COMPARATIVE EVALUATION OF ACCURACY OF IMPLANT LEVEL IMPRESSIONS OBTAINED WITH CLOSED TRAY PRESS FIT IMPRESSION COPINGS AND OPEN TRAY SPLINTED IMPRESSION COPINGS FOR MULTIPLE IMPLANTS - AN IN VITRO STUDY

Dissertation Submitted to

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BRANCH I

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CERTIFICATE

This is to certify that the dissertation titled **"COMPARATIVE EVALUATION OF ACCURACY OF IMPLANT LEVEL IMPRESSIONS OBTAINED WITH CLOSED TRAY PRESS FIT IMPRESSION COPINGS AND OPEN TRAY SPLINTED IMPRESSION COPINGS FOR MULTIPLE IMPLANTS - AN IN VITRO STUDY"** is a bonafide record work done by **Dr. SANKARA KRISHNAN.S** under our guidance and to our satisfaction during his post graduate study period between 2009 – 2012.

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INTRODUCTION

The use of dental implants has revolutionized prosthodontics and the fixed treatment options that can be offered to patients. High survival rates and long- term predictability for clinically loaded endosseous implants have been consistently reported resulting in one of the most successful treatment modalities in dentistry.[3,10,40,60] Predictable success in implantology can be achieved by paying attention to diagnosis and treatment planning, implant surgical procedures, impression making, passive fit of prosthesis, occlusion and recall maintenance.[18,22,23,33,46] Implant failures can be either early failures or late failures. Early failures occur primarily due to inappropriate surgical planning and execution. On the other hand, inappropriate prosthodontic planning, lack of passive fit or occlusal discrepancies leads to late failures occurring due to excessive or inappropriate load transfer to the implants.[41]

Passive fit between prosthesis and implants known as ‘ideal fit’, is considered a significant factor in preventing mechanical and biologic failures in treatment with dental implants.[4] Lack of passive fit of the framework induces internal stress in the prosthesis, implant abutment interface, implant fixture, implant bone interface and the bone matrix, therefore leading to adverse biomechanical problems like screw loosening, fatigue fracture of components, peri implant bone loss and later loss of osseointegration.[9,49,52,55] The degree of misfit varies, depending on the inaccuracies incorporated during the various stages of framework fabrication. The clinically acceptable level of discrepancy of the framework has been reported in the range of 10μm to 150μm based on various clinical studies.[26,30,50,56] Even though the implant components and bone appear to tolerate a degree of misfit without adverse biomechanical problems, it is appropriate to ensure passive fit of the frame work to the implant. Passive fit of the framework largely depends on accurate impression techniques for the accurate reproduction of the inter implant relationship in the working cast.[44] Several other strategies such as CAD/CAM machining, soldering, laser welding have also been suggested to achieve passive fit.[13,45,46,57]

The accuracy of the impression therefore remains a critical factor in determining a precise fit.[57] Various factors such as type of impression technique, different connection level (implant level and abutment level),[1,35] different impression trays[8,53], implant depth[36], time delay for stone pouring and impression material of choice[12,17,25] have been shown to influence the accuracy of impression.[20,21,33,37] Several impression techniques have been advocated for implant impressions to ensure the passive fit of prosthesis.[5,7] The different impression techniques advocated in the literature for implant level impressions include indirect (closed tray) and direct (open tray) techniques.[8,19,59]

Indirect technique (closed tray) involves the use of tapered impression copings which do not get picked up in the impression. It requires the repositioning of the impression copings with the analogs attached to it back in to the impression. The advantage of this technique is that the implant replicas are visually fastened to the impression copings and therefore ensuring its complete seating. But on the other hand the reseating of the coping in the impression may not be accurate, which can reflect as an error in the inter implant relationship in a vertical axes. The instances of the impression material being distorted or damaged is also possible while using the closed tray impression technique in multiple implant situations, especially if implants are not parallel to each other.[2,14,57]

Direct technique (open tray) uses square impression copings that are picked in the impression and the analogs are connected to the copings. The primary advantage is that, the coping remains in the impression and the chances of error during reseating of the impression coping back into the impression is eliminated. The concern of the angulated implants deforming the impression material upon removal of impression does not exist.[14,29] The limitation includes blind fastening of the analog that can result in rotation of the impression coping inside the impression and therefore an error in the inter implant relationship in the horizontal axis can occur.[2,57]

Splinting of open tray impression copings has been suggested by many authors in order to maintain a more accurate inter implant relationship, when compared to that obtained with non-splinted impression copings.[20,28,44,56] Resin, impression plaster, silicones and bite registration polyether have been used as splinting material in several studies.[2,15,21,24,26,28,46,50] Rigid splinting of impression coping with pattern resin have been advocated to achieve accurate open tray impression by various authors.[20,21,28,56]

The above mentioned techniques may be uncomfortable for the patient and the clinician while the impression copings are being screwed and unscrewed intra orally. Slight movement of the copings may result in deformation of the impression material while unscrewing the guide pins from the impression copings during tray removal, or screwing/replacing the matching implant replicas in the impression tray.

There are several studies comparing the accuracy of open tray and closed tray impression copings. Results of studies have shown that open tray copings have a better accuracy than the closed tray transfer copings.[26,28,50] Impression copings that get engaged into the implant without the necessity of a screw has been developed and also reported in the literature.[43,48] These copings get locked into the implant by frictional means on application of a vertical pressure. Such impression copings have been named as press fit impression copings.[43,48] The press-fit impression coping is easier to handle, time saving, and more comfortable for both the clinician and patient because the coping is connected to the implant by pressing instead of screwing. The press-fit coping design allows removal of the coping with the impression and has the advantage of both the open- and closed-tray implant impression techniques. Thus the press-fit impression coping can be said to overcome movement of impression copings inside the impression material.[43, 48] Also, plastic, press fit closed tray impression coping can be adjusted to suit complicated implant positioning for making accurate implant level impressions.[48] However scientific literature on the accuracy of impressions obtained with press fit impression copings is lacking.

Several methods of comparing the accuracy of impressions include strain gauge method and measuring method have been described in the literature to evaluate the accuracy of implant impressions.[33] Measurement of the distances between the implant replicas in the master model and comparing them with that of the experimental model have been reported in the previous studies.[54,55,58] Devices like travelling microscope, digital micrometer, measuring microscope, optical scanner, profile projector have been used for this purpose. It is necessary to study the inter implant distances in x, y and z axis and also the angular measurements in z-axis in order to study the linear and rotational distortion of the impression copings and implant replicas. Coordinate measuring machine (CMM) is an appropriate device to measure the inter implant distances and angulations in the three axes.[31] A Coordinate measuring machine is a device which measures the distance of the analogs from a reference point in the three different axes(x, y and z axes). CMM can calculate the amount of rotational distortion as well as calculate linear rotation. It can also measure the inter implant angulation.[21]

Previous studies have evaluated the inter implant distance variations in one or two axes in the cast retrieved from the impressions.[54,55] Inaccuracies in impression can result in three dimensional changes in inter implant relationship. Therefore there is a need for evaluation of master casts in all the three axes. There are very few studies which combinedly evaluate the inter implant distances in casts, in x, y and z axes as well as the inter implant angulations.[21,46] Scientific evidence regarding the accuracy of master casts obtained from impression made with press fit impression copings and its comparison with other impression techniques are lacking. Therefore, there is a need to analyse and understand the impression technique that would best suit the requirements in a particular clinical situation, to achieve a three dimensionally accurate working cast for fabrication of a passively fitting implant framework.

Hence this in vitro study was aimed to comparatively evaluate the accuracy of implant level impressions obtained with closed tray press fit impression copings and open tray splinted impression copings for multiple implants. Also added to the aim of the study are the following objectives:

1) To evaluate the accuracy of implant level impressions obtained with closed tray press fit impression copings in x axis.
2) To evaluate the accuracy of implant level impressions obtained with closed tray press fit impression copings in y axis.
3) To evaluate the accuracy of implant level impressions obtained with closed tray press fit impression copings in z axis.

4) To evaluate the accuracy of implant level impressions obtained with open tray splinted impression copings in x axis.
5) To evaluate the accuracy of implant level impressions obtained with open tray splinted impression copings in y axis.
6) To evaluate the accuracy of implant level impressions obtained with open tray splinted impression copings in z axis.
7) To compare the accuracy of implant level impressions obtained using closed tray press fit impression technique and open tray splinted impression technique in x-axis.
8) To compare the accuracy of implant level impressions obtained using closed tray press fit impression technique and open tray splinted impression technique in y-axis.
9) To compare the accuracy of implant level impressions obtained using closed tray press fit impression technique and open tray splinted impression technique in z-axis.

REVIEW OF LITERATURE

Eames WB et al (1979)[17] evaluated the effect of an impression material on the accuracy of the impression. The trays were divided into three groups based on the spacer thickness. Group 1 had 2mm thick spacer, group 2 had 4mm thick spacer while group 3 had 6mm thick spacer. The results showed that the most accurate impressions were obtained using a 2mm spaced tray for all the materials tested.

Valderhaug J et al (1984)[53] evaluated the dimensional stability of elastomeric impression materials in stock and custom trays. The elastomeric impression materials used were impregum, xantopren light body and medium body. The results showed that all the measurements except one compiled with the requirements for dimensional stability of rubber impression materials

Spector MR et al (1990)[50] determined the accuracy of three different impression techniques. Three impression methods were used-i) transfer coping united with autopolymerizing resin and dental floss, impression made with polysulfide , ii)polyvinyl siloxane impression was made in a stock tray over a hydrocolloid transfer copings, iii) condensation silicone impression was made in a stock tray over hydrocolloid transfer copings. Results showed measurable distortions occurred in all three techniques and it demonstrated the potential for distortion with the transfer technique used.

Barrett MG et al (1993)[5] performed this study to determine the accuracy of six different impression techniques. The techniques involved were tapered copings with i) alginate ii) polyvinyl siloxane; square copings with i) plaster ii) polyether iii) polyvinylsiloxane iv) splinting of copings with autopolymerizing resin and dental floss before making polyvinyl siloxane impression. Statistical analysis showed no significant difference between the different materials.

Hsu C et al (1993)[26] performed this study to compare the influence of four implant transfer techniques and two master cast methods on the accuracy of abutment position. Groups were i) nonsplinted copings ii)copings secured with dental floss and Duralay resin iii) copings secured with orthodontic wire and Duralay resin, iv)copings secured by prefabricated resin block with .The master cast methods were i)solid cast and ii) Zeiser system. Impressions were made with polyether (Impregum f) material. The results showed that i) the Duralay resin used for splinting is insignificant ii) there is no significant difference between splinted and unsplinted implant copings and iii) with the zeiser system, it was possible to get reduced inter abutment error.

Inturregui JA et al (1993)[28] evaluated the accuracy of three impression techniques for osseointegrated oral implants. Impressions were made with polyether, polyether and impression plaster, and polyether and acrylic resin for splinting. The results showed that none of the techniques resulted in an absolute passive fit.

Assif D et al (1994)[2] described a modified impression technique for implant –supported restoration. The technique involves making a preliminary impression with irreversible hydrocolloid to get a stone model. In this model, an autopolymerising resin custom tray is fabricated with sufficient space for the impression material. Impression is made and after it sets, the excess is cut flush with the tray. The copings are then splinted externally with the tray using autopolymerising resin the incremental manner.

Jemt T et al (1996)[31] evaluated four systems for measuring fit at the implant prosthesis interface. The four systems were a) University of Washington, b) Mylab system c) Photogrammeteric measurement system d) University of Michigan system. Results showed that all four methods are comparable to each other in detecting misfit. The Mylab system was found to be the most repeatable system. Photogrammetery was the only system to evaluate the misfit intraorally.

Reidy SJ et al (1997)[47] evaluated the fit of implant frameworks fabricated by two different techniques namely one-piece cast framework and Procera machined and laser welded frameworks with the help of laser videography. The results showed that laser welded frameworks were more precise than the one piece castings. The mean z-axis gaps were greater for the one piece castings (35µm) when compared to machined titanium laser welded frameworks (25µm).

Burawi C et al (1997)[7] conducted this study to compare the accuracy of a splinted with an unsplinted impression technique. results showed that the plastic impression caps used in the unsplinted impression technique were superior to the resin splinted technique for the transfer of the position of the intraoral bone-lock implants to a laboratory master cast.

Wee AG et al (2000)[57] compared the amount of torque to rotate a square impression coping in an impression and evaluated the accuracy of solid implant casts fabricated from different impression materials. Polyether, addition silicone and polysulfide were made using each material. The results showed that the highest torque values were obtained for polyether which was contributed to the rigidity of the material. Polyether and addition silicone gave more accurate casts than polysulfides.

Herbst D et al (2000)[24] assessed the dimensional accuracy of casts obtained from four impression techniques i)tapered impression copings not splinted together ii) square impression copings splinted together iii) square impression copings splinted with autopolymerising acrylic resin iv)square copings with lateral extension on one side, not splinted. Results showed that the dimensional accuracy of was exceptional for all the impression techniques. The author attributed this to the property of the addition silicone in achieving accurate impressions.

Vigolo P et al (2000)[54] compared the master cast accuracy for single tooth implant replacement when non-modified and modified impression copings were used. The results showed that modified impression copings had a significantly lesser amount of rotational movement than unmodified impression technique.

Vigolo P et al (2003)[55] in their in vitro study evaluated the accuracy of three impression techniques using polyether impression material. Fifteen impressions were made in each group, in group 1 non modified impression copings were used. In group 2, impression copings were connected using Duralay resin. In group 3, impression copings were air abraded and coated with adhesive. Results showed that i)none of the casts of group 1 allowed for the seating of metal template and ii) the master casts obtained by splinting the copings and air borne particle abrasion were accurate.

Burns J et al (2003)[8] performed an in vitro study to study whether custom trays produce more consistently accurate implant fixture level impressions than stock trays, by use of an open tray technique. The results showed that rigid custom trays (close fit and spaced) produced significantly more accurate impressions than flexible stock polycarbonate trays.

Nicholas E et al (2004)[18] described a two stage impression technique using an elastomeric material and impression plaster for implant impression for either completely or partially edentulous patients. This technique combines the flexibility of the elastomeric impression material for capturing the impression plaster to improve the accuracy of fit of the prosthetic components.

Windhorn RJ et al (2006)[59] described an open tray technique for impression implants. In this technique, a custom acrylic resin tray was fabricated with an opening in the area where the implants were located. Impression posts were screwed on to the implants. A section of boxing wax was adapted over the openings in the tray and sealed to the tray. Light body addition silicone was injected around the impression posts wile medium or heavy body VPS material was filled in the tray. In the area of wax alone, Blu mousse Classic was added in the tray and the impression made.

Lee H et al (2008)[37] investigated the accuracy of published implant impression techniques and examined the clinical factors affecting implant impression accuracy. The results of his investigation showed that greater accuracy was in splinted technique than with the non splint technique and in studies with 4 or more implants, open tray technique showed more accuracy than closed tray technique.

Wenz HJ et al (2008)[58] investigated the deviations of the implant positions of both impressions and casts using 5 different impression techniques with polyether and polyvinyl siloxane as impression material. The measurements for the casts in horizontal plane was made using a computer aided microscope. Results showed that casts obtained using indirect impression techniques with addition silicone would affect the clinical fit of implant retained superstructures.

Lee YJ et al (2009)[38] compared the accuracy of four implant level impression techniques for angulated implants. Four groups were included: a) octagonal transfer impression coping b) non octagonal transfer impression coping c) non-octagonal pick up impression coping d) non-octagonal pick up impression coping splinted with acrylic resin. Results showed that casts produced from non octagonal impression techniques were more accurate then those produced by other impression techniques.

Nissan J et al (2009)[43] described the use of press fit, closed tray impression copings as a mechanism suitable for an implant level cast. At first the copings were connected to the implant by pressing on instead of screwing and fit was verified radiographically and impression taken. After impression sets the impression is removed from mouth with the press fit copings and the replicas wee connected.

Selecman AM et al (2009)[48] described the use of solid, plastic pressfit coping for clinical case. In that case report two implants were placed in the area of left maxillary molar and second premolars. Upon radiographic examination it was noted that the implants were less than 2mm apart from restoration platform and had an estimated angulation of 20 degrees. Solid plastic press fit copings were used in this case as impression copings. First distal copings were placed and anterior coping was conservatively modified until it could be placed conservatively and impression made.

Del' Acqua MA et al (2010)[16] compared the dimensional accuracy of a stone index and of two impression techniques. Three groups of impressions were tested namely: index (I), squared (S), modified squared (MS). The accuracy was evaluated using stereomicroscope. The results showed that the index and modified squared generated more accurate casts than the squared technique.

Mostafa TNM et al (2010)[42] evaluated the precision of three transfer techniques using two impression materials. This study compared the accuracy between direct technique splinted and unsplinted and indirect technique with two impression materials namely polyether and polyvinylsiloxane. A travelling microscope was used to make six measurements for each cast. Results showed that there was no statistical significance difference between the impression materials regarding the accuracy.

Hariharan R et al (2010)[21] evaluated the accuracy of casts obtained from non-splinted and splinted impression techniques employing various splinting materials for multiple implants. Impressions were divided into four groups: a) non-splinted technique b) acrylic resin splinted technique c) bite registration addition silicone d) bite registration polyether splinted technique and accuracy was measured using CMM. Results showed that polyether bite registration silicone showed more accuracy.

Alikhashi M et al (2011)[1] compared the three dimensional accuracy of implant level impression method and abutment level impression method and also its effect on marginal discrepancy. The accuracy was measured using CMM. The results showed that implant level accurately transferred the angulated position of implants and the impression method did not affect the level of marginal discrepancy.

Kwon JH et al (2011)[35] evaluated and compared the three dimensional accuracy of master casts obtained with and without impression copings. Groups involved were I) impressions using open tray copings II) impressions obtained without using impression copings. The accuracy was measured using CMM. Results showed that casts obtained using open tray impression copings was more accurate than casts obtained without using impression copings.

Jang HK et al (2011)[29] determined the accuracy of implant level impressions for angled implants. Five groups were created according to the angle of divergence (0, 5, 10, 15 and 20 degrees). The divergent angle in each study model was verified with the profilometer. The results showed that the implants with 15 degree divergences was accurate and concluded that the inaccuracy of impression increases with increase in the angle of divergence.

MATERIALS AND METHODS

This in vitro study was aimed to comparatively evaluate the accuracy of implant level impressions obtained with closed tray press fit impression copings and open tray splinted impression copings for multiple implants.

Materials:

The following materials were used in the study.

1. Mandibular edentulous model former (Ashoosons, Delhi, India) (Fig.19)
2. Modelling wax (Cavex , Holland BV , The Netherlands) (Fig.1)
3. Impression coping closed tray (NoblRpl RP, REF 35406, Nobel Biocare AB , Sweden) (Fig.2)
4. Implant replica and cover screw (NobRpl RP, REF 29500, Nobel Biocare AB, Sweden) (Fig.3a & 3b)
5. Press fit impression coping, plastic (NoblRpl RP, REF 35406, Nobel Biocare AB , Sweden) (Fig.4)
6. Impression coping open tray (NoblRpl RP, REF 33539 , Nobel Biocare AB , Sweden) (Fig.5a & 5b)
7. Manual prosthetic torque wrench (REF 29165 , Nobel Biocare AB, Sweden) (Fig.6a)
8. Screw driver manual unigrip 28mm (REF 29149, Nobel Biocare AB, Sweden) (Fig. 6b)

9. Heat cured acrylic resin (DPI heat cure India) (Fig.7a & 7b)
10. Separating media (DPI heat cure cold mould seal , India) (Fig.7c)
11. Irreversible hydrocolloid (Algimat ,India) (Fig.8)
12. Type IV dental stone (Ultrarock, Kalabhai, India) (Fig.9)
13. Polyether tray adhesive (3m ESPE AG, Seefeld, Germany) (Fig.12)
14. Light cure resin sheets (Plaque Photo, W+P Dental, Hamburg, Germany) (Fig.13)
15. Polyether impression material (Impregnum penta, 3M AG, Seefeld, Germany) (Fig.14)
16. Pattern resin (GC pattern resin, Osaka, Japan) (Fig.15)

Equipments:

The following equipments were used in the study:

1. Pentamix 2, (3M AG, Seefeld, Germany) (Fig.17)
2. Light cure unit (Delta, India) (Fig.11)
3. Coordinate measuring machine (CMM) (Spectra, Accurate, Pune, India) (Fig. 37).
4. Dental surveyor (Paraflex, Bego, Germany) (Fig.16).
5. Vibrator(Fig.10) (Delta, India)

Description of Pentamix automatic mixing unit (Fig.17):

The Pentamix automatic mixing unit (3M AG , Seefeld , Germany)(Fig 17) was used in the present study to obtain a homogenous mix of medium viscosity polyether impression material. The Pentamix automatic Mixing Unit essentially consists of three components namely : Drive unit with motors, clutch and gears, Dispensing unit consisting of chain, cross-member, double plunger and piston discs and Superstructure with frame, side sections made of die-cast aluminum and polycarbonate housing. The clutch is a particularly important component. It is responsible for transmitting the enormously high torque levels, while at the same time acting as an overload safety device.

It must disengage the drive unit reliably from the dispensing unit when the material in the foil bag has been used up. The clutch also provides defined, delayed disengaging each time dispensing finishes in order to prevent the pastes from dripping.

Description of Coordinate Measuring Machine (CMM) (Fig.41):

In this present study Coordinate Measuring Machine (CMM) (Spectra, Accurate, Pune, India) (Fig 37) was used to evaluate the inter implant distances and angulations in three axes (x, y and z axes). The typical "bridge" CMM is composed of three axes, an X, Y and Z. These axes are orthogonal to each other in a typical three dimensional coordinate system. Each axis has a scale system that indicates the location of that axis. The machine will read the input from the touch probe, as directed by the operator or programmer. The machine then uses the X, Y, Z coordinates of each of these points to determine size and position with micrometre precision typically.

Coordinate measuring machine (CMM) is also a device used in manufacturing and assembly processes to test a part or assembly against the design intent. By precisely recording the X, Y, and Z coordinates of the target, points are generated which can then be analysed via regression algorithms for the construction of features. These points are collected by using a probe that is positioned manually by an operator or automatically via Direct Computer Control (DCC).

METHODOLOGY:

The methodology of this study has been divided into the following stages:

I. Reference model fabrication
II. Evaluation of reference model using Coordinate measuring machine
III. Custom tray fabrication
    a. Preparation of primary cast
    b. Preparation of spaced primary cast
    c. Fabrication of custom tray
IV. Implant impressions
V. Preparation of master casts
VI. Evaluation of master casts using Coordinate measuring machine
VII. Results and statistical evaluation

I. REFERENCE MODEL FABRICATION(Control-Group R): (Fig. 19, 20 & 21)

A wax model of the edentulous mandibular arch was obtained by flowing modelling wax (Cavex , Holland BV, The Netherlands) (Fig 1)into an edentulous silicone mold (Ashoosons, Delhi, India) (Fig 19a). The wax model (Fig.19b) was then mounted on a dental surveyor and four implant replicas (NobRpl RP, REF 29500, Nobel Biocare AB, Sweden) (Fig 3a) of diameter 4.3mm were incorporated into the model parallel to each other in the mandibular symphyseal region (Fig.20a & b). The analogs were placed in a manner such that the one of the trilobes was facing labially. It was also ensured that the 2mm polished collar remained outside the model. Three stops were cut in the land area of the wax model, 5mm x 5mm, one anteriorly along the midline and one on either side posteriorly, to act as stops for the custom tray during impression making. The stops were made to ensure similar orientation of all the custom trays on the reference model. Cover screws (NobRpl RP, REF 29434, Nobel Biocare AB, Sweden) (Fig 3b) were screwed on to the implant replicas and an acrylic reference model was obtained by processing the wax model in heat cure acrylic resin (DPI Heat cure, India) (Fig 7a and b). The reference model was finished and kept undisturbed for 24 hours before impression making (Fig.21).

II. EVALUATION OF REFERENCE MODEL(Control-Group R) USING COORDINATE MEASURING MACHINE: (Fig.42)

The reference model was evaluated using a Coordinate measuring machine (CMM, Accurate Spectra, Pune, India) (Fig 41), which is capable of measuring in x, y and z axes with an accuracy of ±5μm. The CMM was connected to a data processor (Accusoft) which gave the measured values. In order to measure the three dimensional accuracy of the reference model, the inter implant distances in x, y and z axes were measured and the angle between the implant replicas around the z-axis were evaluated. The implant replicas were numbered 1 to 4 starting from the left posterior replica to the right posterior replica.

The probe used in the CMM was first calibrated. The reference model was measured to obtain the reference values. The model was screwed in the base for measuring. In order to obtain similar orientation of the reference model and all the master casts, the centre of replicas 1 and 4 were aligned in the CMM and then the measurements were made (Fig.42).

Measurements were made in all the three axes namely x, y and z. The distance between replica 1 and 2 was denoted as D_1. The distance between replica 1and 3 was denoted as D_2. The distance between replica 1 and 4 was denoted as D_3. The angulation between replica 1 and 2 was denoted as Angle 1. The angulation between replica 1 and 3 was denoted as Angle 2 and the angulation between replica 1 and 4 was noted as Angle 3.

Measuring distance in x axis (Fig.44):

The coordinates of the centre of replica 1 was measured and zeroed. Keeping this position as a reference, the positions of the centre of replica 1 and 2(D_1x), 1 and 3(D_2x), and 1 and 4(D_3x) were measured in the x plane (Fig.44).

Measuring distance in y axis (Fig.45):

The coordinates of the centre of replica 1 was measured and zeroed. Keeping this position as a reference, the positions of the centre of replica 1 and 2(D_1y), 1 and 3(D_2y), and 1 and 4(D_3y) were measured in the y plane (Fig.45)

Measuring distance in z axis (Fig.46):

Then the probe was used to measure the plane formed by the platform of replica 1. The distance between the planes formed by the replica platforms were measured. The distance between the plane formed by the replica platform number 1 and 2(D_1z), 1 and 3(D_2z) and 1 and 4(D_3z) were measured to get the inter implant distance in the z axis (Fig.46).

Measuring angulations in z axis (Fig.47):

In order to find the angular relationship between the replicas, the open tray impression copings were connected to the implant replicas and screwed at 15Ncm torque. The plane formed by the flat surfaces of each impression coping were measured. The angle formed between the implant replicas 1 and 2 (Angle1), 1 and 3 (Angle 2) and 1 and 4 (Angle 3) were measured by calculating the angle formed by the flat surfaces of the respective impression copings (Fig.47). Each measurement on the reference model in all the three axes were measured 5 times and the mean measurements were obtained. All the measurements were made by a single operator to avoid inter operator error.

III. FABRICATION OF CUSTOM TRAYS (Fig 22-27):

III a. Preparation of primary cast (Fig.22 & 23)

Four tapered impression copings (NobRpl RP, REF 33540, Nobel Biocare AB, Sweden) (Fig.2) were screwed onto the implant replicas of the reference model (Fig.22a) at a torque of 15Ncm using a manual torque wrench (REF 29165, Nobel Biocare AB, Sweden) (Fig.6a). An irreversible hydrocolloid (Neocolloid, Zhermack, Italy) (Fig.8) impression was made and the tapered impression posts- the implant replica complex repositioned in the impression (Fig.22b). Stone cast was obtained using type IV dental stone (Kalabhai, India) (Fig.9). This cast was used as the primary cast (Fig.23).

III b. Preparation of spaced primary cast (Fig.24-26):

A uniform spacer of 3mm was formed over the primary cast (Fig.24) by adapting two layers of modelling wax. An impression of this primary cast with wax spacer was made using irreversible hydrocolloid (Fig.25) and a cast was poured using type IV dental stone (Kalabhai, India) (Fig.9) to obtain a spaced primary cast(Fig.26). All the custom trays to be used in this study were fabricated using this spaced primary cast for both open and closed tray techniques.

III c. Custom tray fabrication (Fig.27a & 27b):

20 custom trays, 10 for open tray impression and 10 for closed tray impression technique were fabricated using light polymerising acrylic resin (Plaque Photo, W+P dental, Hamburg ,Germany) (Fig.13) and light curing box unit(Fig.11). All 20 trays were fabricated on the same spaced primary cast, so as to standardise the spacer thickness. Tin foil substitute (DPI, India) was applied onto the spaced primary cast and was allowed to dry. A 2mm thick, light polymerising resin sheet was adapted onto the cast. Care was taken to incorporate the resin into all the three stops that were previously created on the land area of the reference model. For open tray fabrication, a window was created anteriorly corresponding to the location of the implant impression posts. For closed trays, window in the location of the implants was not made. The excess material was cut away, following which the handles were attached. For the open tray impression, trays were fabricated with three handles. Two handles posteriorly on the lateral aspect of the tray and one handle in the anterior region were attached. For the closed tray impression, trays were fabricated with only two handles which were attached posteriorly on the lateral aspect of the tray. The curing of the adapted trays was carried out as per manufacturer's instructions. The casts with the adapted resin were placed

inside the light curing unit for 6 minutes. The tray was removed from the cast and kept inside the curing unit for another 6 minutes. In this manner, 10 custom trays were made for open tray impressions (Fig.27a) and 10 custom trays were made for closed tray impressions (Fig.27b). All the trays were left undisturbed for 24 hours, for the trays to become dimensionally stable prior to impression making.

IV. IMPLANT IMPRESSIONS

The custom trays obtained in the above mentioned manner were employed for impression making. Impression techniques were divided into two groups namely:

GROUP A - Implant level impression technique with closed tray press fit impression copings.

GROUP B – Implant level impression technique with open tray splinted impression copings.

The procedure adopted for making impressions for Group A and Group B is detailed subsequently:

GROUP A – Implant level impression technique with closed tray press fit impression copings (Fig.28-32):

The closed tray press fit copings were connected to the implant replicas by pressing onto it (Fig.28). Complete seating of the press fit copings was ensured by visual inspection of the model. The custom trays was coated with a uniform layer of polyether adhesive (3M ESPE, Germany) (Fig.12) and allowed to dry for fifteen minutes as per the manufacturer's recommendation (Fig.29). Medium body polyether was machine mixed (3M ESPE Pentamix 2, Germany) (Fig.17) and loaded into the custom tray keeping the tip immersed in the material all the time (Fig.30). It was also syringed around the impression copings by another operator. The tray was then positioned over onto the reference model immediately and the impression was made (Fig.31).

While positioning, care was taken to ensure that the tray seated completely in the three stops that were made in the reference model to ensure complete seating and proper positioning of the custom tray. The excess material along the borders of the tray was removed. The impression was allowed to set undisturbed for six minutes as per the manufacturer's recommendation. A total of 10 such impressions were made. After ensuring the complete set of the impression material, the tray with the impression was retrieved from the reference model (Fig.32).

GROUP- B – Implant level Impression Technique With Open Tray Impression Copings. (Fig.35-38)

The open tray impression copings with long guide pins were screwed onto the implant replicas of the reference model at a torque of 15Nm using the calibrated manual torque wrench. An index was made around the impression copings in the reference model using putty consistency addition silicone to act as a scaffold for the resin splinting material and to prevent the flow of the resin towards the implant. The index was sectioned into a labial and lingual half so as to facilitate its removal after polymerisation of the splint material. The index was repositioned on the reference model. Pattern resin (GC pattern resin, Osaka, Japan) (Fig.15) was added around the impression copings by brush bead method to splint the copings together (Fig.35a). The splint was allowed to polymerise undisturbed for 4 minutes. The splint was then sectioned in-between the impression posts using a thin separating disc to relive the stresses caused due to polymerisation shrinkage. The cut sections were then rejoined using the same pattern resin by applying it using the "brush bead" method. This was again allowed to polymerise for 4 minutes. The putty index was later removed. The reference model-impression copings assembly was now ready for impression making (Fig.35b).

The custom tray and the resin splint were coated with a uniform layer of polyether adhesive (3M ESPE, Germany) (Fig.12) and allowed to dry for fifteen minutes as per the manufacturer's recommendation (Fig.36). Medium body polyether was machine mixed (3M ESPE Pentamix 2, Germany) and loaded into the custom trays keeping the tip immersed in the material all the time. It was also syringed around the impression copings by another operator. The tray was then positioned over and seating onto the reference model immediately and the impression was made (Fig.37).

It was made sure that the tray seated completely in the three stops that were made in the reference model to ensure complete seating and proper positioning of the custom tray. The excess material that had flown over the top of the posts through the window in the custom tray was removed to expose the screws. The impression was allowed to set undisturbed for 6 minutes as per the manufacturer's recommendation. After ensuring the complete set of impression material, the tray with impression was retrieved from the reference model. The screws of the impression posts were unscrewed and the impression removed from the reference model (Fig.38). A total of ten impressions were made in this group in the similar manner.

V. Preparation of master casts: (Fig.33, 34, 39 and 40)

The impressions made were allowed to polymerise completely and the casts were poured after half an hour as per manufacturer's recommendation. For the copings picked in the closed tray press fit impression the implant replicas were attached by pressing it on to the closed tray copings (Fig.33). Implant replicas were screwed onto the impression posts that were picked in the open tray impressions (Fig.39). Casts were poured using type IV dental stone (Ultrarock, Kalabhai, India) (Fig.9). The stone was hand mixed with water as per the manufacturer's recommended ratio of 100 gram to 20ml and vibrated in a vibrator (Confident equipments, India) (Fig.10) to minimize air bubble incorporation. The same quantity of dental stone was used for pouring all the casts. The cast was allowed to set for two hours and later retrieved from the impressions (Fig.34 & 40). For all the open tray impressions, the impression copings were unscrewed before retrieval of the cast. All casts were labelled 1 to 10 according to the group. A total of 20 master casts were thus obtained (10 casts for Group A and 10 casts for Group B).

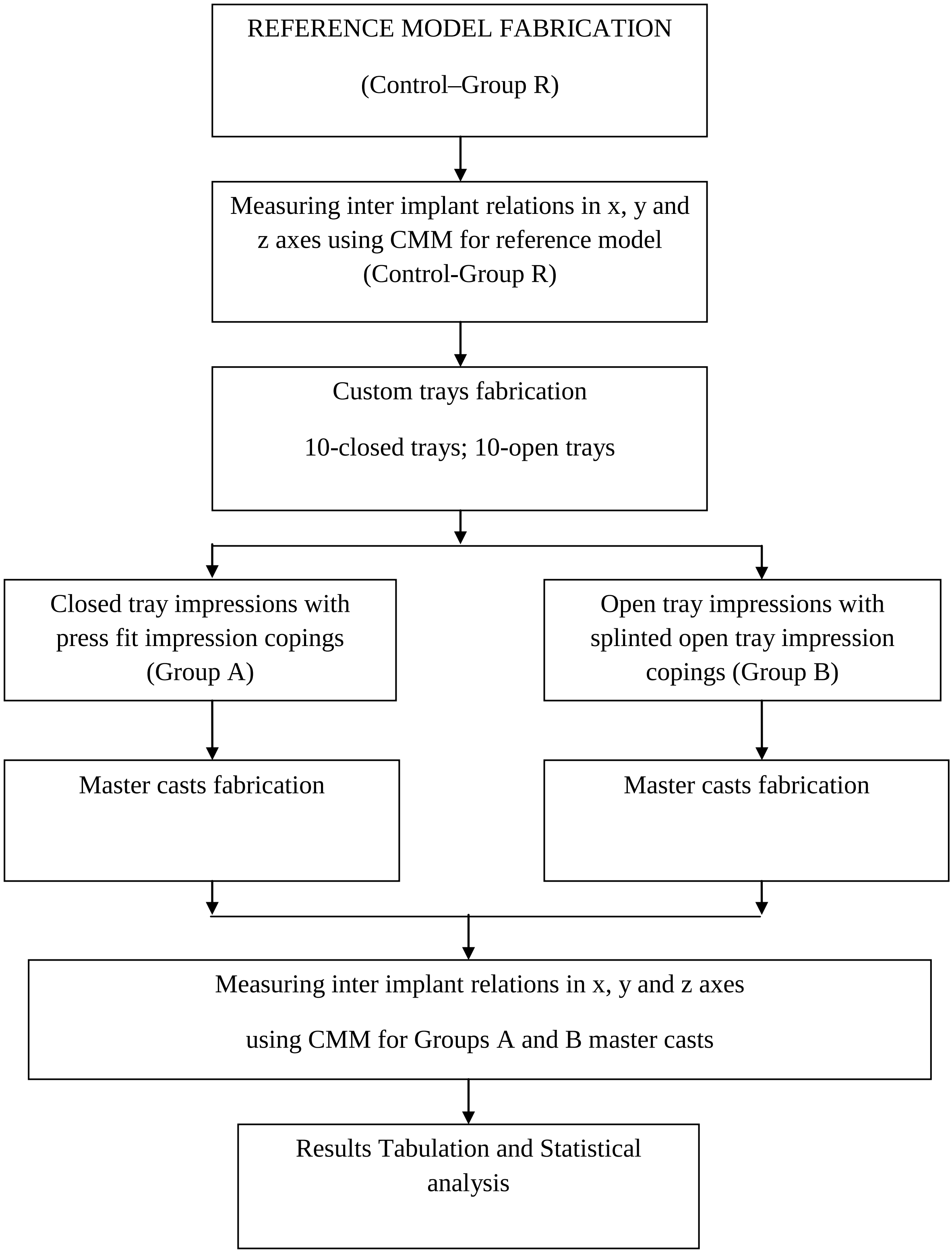
VI. Evaluation of master casts: (Fig.43-47)

The casts obtained from the different impressions were grouped according to the respective techniques and numbered from 1 to 10 in each group. All 20 casts of Group A and Group B were evaluated using a Coordinate measuring machine (CMM, Accurate Spectra, Pune, India) (Fig.43) in a similar manner as it was done for the reference model. The measurements were made in all the three axes namely x, y and z (Fig.44-47).

VII. RESULTS AND STATISTICAL ANALYSIS:

The mean values of all the measurements for each group were obtained and they were statistically analysed using one way ANOVA and Student Newmann Keuls tests at a significance of 0.5 using SPSS 11.5 software, tabulated and inferences drawn.

METHODOLOGY OVERVIEW



METHODOLOGY

REFERENCE MODEL FABRICATION

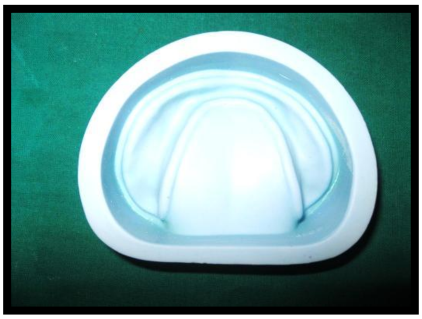


Fig.19a: Edendulous model former

Fig.19b: Edentulous wax model

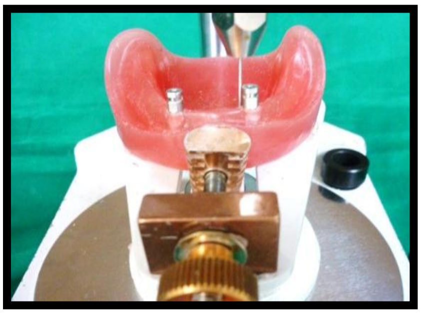


Fig.20a : Implant replicas incorporated in wax model

Fig.20b: Finished wax model with replicas

Fig.21: Finished reference model in heat cure acrylic resin

RESULTS

The present in vitro study was conducted to comparatively evaluate the accuracy of implant level impression obtained with closed tray press fit impression copings and open tray splinted impression copings for multiple implants.

The following results were obtained from the study which compared the inter implant distances in x, y and z axis and the angular relationships between the implants in z axis. These four parameters were compared between the reference model (Control-Group R) and test groups (Group A and Group B).

Mean and standard deviation (S.D) of all the values for each group were obtained and they were statistically analyzed by using one way ANOVA and Student-Newman-Keuls test.

Table 1-3 shows the basic values, mean and standard deviation of inter implant distances in x-axis for the reference model (Control-Group R) and the test groups (Group A and Group B).

Table 4-6 shows the basic values, mean and standard deviation of inter implant distances in y-axis for the reference model (Control-Group R) and the test groups (Group A and Group B).

Table 7-9 shows the basic values, mean and standard deviation of inter implant distances in z-axis for the reference model (Control-Group R) and the test groups (Group A and Group B).

Table 10-12 shows the basic values, mean and standard deviation of inter implant angulations in z-axis for the reference model (Control-Group R) and the test groups (Group A and Group B).

Table 13 shows the comparison of mean inter implant distances for Control-Group R, Group A and Group B samples in x axis.

Table 14 shows the differences in mean inter implant distances between Control-Group R, Group A and Group B samples in x-axis.

Table 15 shows the comparison of mean inter implant distances for Control-Group R, Group A and Group B samples in y axis.

Table 16 shows the differences in mean inter implant distances between Control-Group R, Group A and Group B samples in y-axis.

Table 17 shows the comparisons of mean inter implant distances for Control-Group R, Group A and Group B samples in z axis.

Table 18 shows the differences in mean inter implant distances between Control-Group R, Group A and Group B samples in z-axis.

Table 19 shows the comparison of mean inter implant angulations for Control-Group R, Group A and Group B samples in z axis.

Table 20 shows the differences in mean inter implant angulations between Control-Group R, Group A and Group B in z-axis.

Table 21 shows the comparative evaluation of mean differences in inter implant distances between reference model (Control-Group R), Group A and Group B samples in x-axis.

Table 22 shows the comparative evaluation of mean differences in inter implant distances between reference model (Control-Group R), Group A and Group B samples in y-axis.

Table 23 shows the comparative evaluation of mean differences in inter implant distances between reference model (Control-Group R), Group A and Group B samples in z-axis.

Table 24 shows the comparative evaluation of mean differences in inter implant angulations between reference model (Control-Group R), Group A and Group B samples in z-axis.

Table 1: Basic values, mean and standard deviation of inter implant distances in x-axis for the reference model (Control-Group R)

CONTROL- GROUP R	D_1x(mm)	D_2x(mm)	D_3x(mm)
R1	8.0600	21.3800	29.1900
R2	8.0390	21.4000	29.1950
R3	8.0500	21.3100	29.1100
R4	8.0500	21.3400	29.1880
R5	7.9890	21.3180	29.1512
Mean / S.D	8.0376/±0.02817	21.3496/±0.03913	29.1668/±0.03624

D_1x – distance between replica 1 and replica 2 in x-axis

D_2x – distance between replica 1 and replica 3 in x-axis

D_3x – distance between replica 1 and replica 4 in x-axis

INFERENCE:

For the reference model the mean inter implant distance in x-axis, between replica 1 and replica 2 (D_1x) is 8.0376mm, between replica 1 and replica 3 (D_2x) is 21.3496mm and between replica 1 and replica 4 (D_3x) is 29.1668mm.

Table 2: Basic values, mean and standard deviation of inter implant distances in x-axis for Group A samples

Group A	D_1x(mm)	D_2x(mm)	D_3x(mm)
A1	8.1970	21.5930	29.3150
A2	8.2850	21.5660	29.1460
A3	8.2170	21.4950	29.2939
A4	8.1930	21.5040	29.2240
A5	8.3020	21.5870	29.1890
A6	8.0390	21.3980	29.1170
A7	7.9800	21.3056	29.1155
A8	8.2350	21.5633	29.3480
A9	7.9500	21.3283	29.6890
A10	7.6800	21.0700	29.0600
Mean /S.D	8.1078/±0.19477	21.4410/±0.16747	29.2497/±0.18122

INFERENCE:

For the Group A samples the mean inter implant distance in x-axis, between replica 1 and replica 2 (D_1x) is 8.1078mm, between replica 1 and replica 3 (D_2x) is 21.4410mm and between replica 1 and replica 4 (D_3x) is 29.2497mm.

Table 3: Basic values, mean and standard deviation of inter implant distances in x-axis for Group B samples

Group B	D_1x(mm)	D_2x(mm)	D_3x(mm)
B1	7.9610	21.2470	29.1360
B2	7.8510	21.1980	29.0194
B3	8.4610	21.3680	29.1960
B4	8.1020	21.4350	29.2390
B5	7.8943	21.2200	29.1140
B6	8.0220	21.3400	29.1930
B7	7.8800	21.2430	29.1130
B8	7.8301	21.1690	29.0530
B9	8.0671	21.3780	29.2170
B10	7.9600	21.3044	29.1400
Mean /S.D	8.0028/±0.18487	21.2902/±0.08795	29.1420/±0.07084

INFERENCE:

For Group B samples the mean inter implant distance in x-axis between replica 1 and replica 2 (D_1x) is 8.0028mm, between replica 1 and replica 3 (D_2x) is 21.2902mm and between replica 1 and replica 4 (D_3x) is 29.1420mm.

Table 4: Basic values, mean and standard deviation of inter implant distances in y-axis for the reference model (Control-Group R)

CONTROL- GROUP R	D_1y(mm)	D_2y(mm)	D_3y(mm)
R1	4.8900	4.8900	2.9240
R2	4.8960	4.8820	2.9220
R3	4.8920	4.8900	2.9500
R4	4.9027	4.9027	3.0000
R5	4.8970	4.8970	2.9730
Mean /S.D	4.8955/±0.00492	4.8923/±0.00786	2.9538/±0.03323

D_1y – distance between replica 1 and replica 2 in y-axis

D_2y – distance between replica 1 and replica 3 in y-axis

D_3y – distance between replica 1 and replica 4 in y-axis

INFERENCE:

For reference model the mean inter implant distance in y-axis, between replica 1 and replica 2 (D_1y) is 4.8955mm, between replica 1 and replica 3 (D_2y) is 4.8923mm and between replica 1 and replica 4 (D_3y) is 2.9538mm.

Table 5: Basic values, mean and standard deviation of inter implant distances in y-axis for Group A samples

Group A	D_1y(mm)	D_2y(mm)	D_3y(mm)
A1	4.4940	4.4940	2.6480
A2	5.0800	5.0800	3.0170
A3	4.2610	4.2610	2.5870
A4	4.3950	4.3950	2.5480
A5	4.3941	4.3940	2.5600
A6	4.7400	4.7400	2.7800
A7	4.8500	4.8500	2.9000
A8	4.9600	4.9600	3.0400
A9	5.1450	5.1450	3.1242
A10	5.3000	5.0300	3.2400
Mean /S.D	4.7619/±0.36172	4.7349/±0.32535	2.8444/±0.25465

INFERENCE:

For Group A samples the mean inter implant distance in y-axis between replica 1 and replica 2 (D_1y) is 4.7619mm, between replica 1 and replica 3 (D_2y) is 4.7349mm and between replica 1 and replica 4 (D_3y) is 2.8444mm.

Table 6: Basic values, mean and standard deviation of inter implant distances in y-axis for Group B samples

Group B	D_1y(mm)	D_2y(mm)	D_3y(mm)
B1	4.8850	4.8850	2.9880
B2	5.0200	5.2670	3.3000
B3	5.3500	5.3300	3.2200
B4	5.1700	4.8900	3.1700
B5	4.8650	4.7600	2.9700
B6	4.9800	4.8800	3.0840
B7	4.8900	4.9800	3.0800
B8	4.9200	4.8600	2.9600
B9	5.0800	4.9800	3.0680
B10	5.0400	4.8900	3.1760
Mean /S.D	5.0200/±0.15135	4.9722/±0.18327	3.1016/±0.11342

INFERENCE: For Group B samples the mean inter implant distance in y-axis between replica 1 and replica 2 (D_1y) is 5.0200mm, between replica 1 and replica 3 (D_2y) is 4.9722mm and between replica 1 and replica 4 (D_3y) is 3.1016mm.

Table 7: Basic values, mean and standard deviation of inter implant distance in z-axis for reference model (Control-Group R)

CONTROL-GROUP(R)	**D_1z(mm)**	**D_2z(mm)**	**D_3z(mm)**
R1	3.3650	2.8700	1.9400
R2	3.2830	2.8400	1.9100
R3	3.3670	2.9390	2.0120
R4	3.3740	2.9570	2.0230
R5	3.3890	2.9460	2.0080
Mean / S.D	3.3556/±0.04166	2.9104/±0.05207	1.9786/±0.05037

D_1z – distance between replica 1 and replica 2 in z-axis

D_2z – distance between replica 1 and replica 3 in z-axis

D_3z – distance between replica 1 and replica 4 in z-axis

INFERENCE:

For reference model the mean inter implant distance in z-axis between replica 1 and replica 2 (D_1z) is 3.3556mm, between replica 1 and replica 3 (D_2z) is 2.9104mm and between replica 1 and replica 4 (D_3z) is 1.9786mm.

Table 8: Basic values, mean and standard deviation of inter implant distances in z-axis for Group A samples

Group A	D_1z(mm)	D_2z(mm)	D_3z(mm)
A1	3.6630	2.6150	1.5000
A2	3.7490	2.4660	1.4380
A3	3.7670	2.5690	1.3800
A4	3.6100	2.9000	1.7300
A5	3.3200	2.9850	1.6000
A6	3.5300	3.0800	2.0700
A7	3.4790	3.5500	1.0500
A8	3.8050	2.8200	1.4200
3.32	3.3100	3.1300	2.4500
A10	3.3740	3.4600	2.9800
Mean /S.D	3.5607/±0.18674	2.9575/±0.36226	1.7618/±0.57951

INFERENCE:

For Group A samples the mean inter implant distance in z-axis between replica 1 and replica 2 (D_1z) is 3.5607mm, between replica 1 and replica 3 (D_2z) is 2.9575mm and between replica 1 and replica 4 (D_3z) is 1.7618mm.

Table 9: Basic values, mean and standard deviation of inter implant distances in z-axis for Group B samples

Group B	D_1z(mm)	D_2z(mm)	D_3z(mm)
B1	3.3950	3.1500	2.3050
B2	3.260	3.5400	2.1642
B3	3.4100	3.1900	1.8900
B4	3.9100	2.7100	1.7900
B5	3.6330	2.4170	1.6260
B6	3.4400	2.3400	1.6700
B7	3.2900	3.0600	1.4500
B8	4.0680	2.5500	1.6800
B9	3.9000	2.8220	1.6900
B10	3.4600	2.3300	1.6500
Mean /S.D	3.5766/±0.28592	2.8109/±0.41351	1.7915/±0.26116

INFERENCE:

For Group B samples, the mean inter implant distance in z-axis between replica 1 and replica 2 (D_1z) is 3.5766 mm, between replica 1 and replica 3 (D_2z) is 2.8109mm and between replica 1 and replica 4 (D_3z) is 1.7915mm.

Table 10: Basic values, mean and standard deviation of inter implant angulations in z-axis for reference model (Control-Group R)

CONTROL-GROUP(R)	Angle 1(degrees)	Angle 2(degrees)	Angle 3(degrees)
R1	20.3512	32.1749	79.5631
R2	20.4331	32.1743	80.1200
R3	20.3539	32.1570	79.4723
R4	20.4349	32.1854	79.5933
R5	20.3534	32.1525	79.5109
Mean / S.D	20.3853/±0.04447	32.1688/±0.01367	79.6519/±0.26579

Angle 1 – angulation between replica 1 and replica 2 in z-axis

Angle 2 – angulation between replica 1 and replica 3 in z-axis

Angle 3 – angulation between replica 1 and replica 4 in z-axis

INFERENCE:

For reference model the mean inter implant angulation in z-axis between replica 1 and replica 2 (Angle 1) is 20.3853º, between replica 1 and replica 3 (Angle 2) is 32.1688º and between replica 1 and replica 4 (Angle 3) is 79.6519º.

Table 11: Basic values, mean and standard deviation of inter implant angulations in z-axis for Group A samples

Group A	Angle 1(degrees)	Angle 2(degrees)	Angle 3(degrees)
A1	20.3513	32.1749	79.5631
A2	20.3513	32.1756	79.5230
A3	19.1125	31.9027	79.5711
A4	19.2041	32.5635	79.4936
A5	19.5529	31.7012	79.4809
A6	19.3954	31.9013	78.2150
A7	19.2119	32.2808	79.5104
A8	19.5142	32.0247	78.5721
A9	19.3608	31.8048	79.4127
A10	19.5754	32.5319	79.1726
Mean /S.D	19.5630/±0.44341	32.1061/±0.29350	79.2510/±0.47368

INFERENCE:

For Group A samples, the mean inter implant angulations in z-axis between replica 1 and replica 2 (Angle 1) is 19.5630º, between replica 1 and replica 3 (Angle 2) is 32.1061º and between replica 1 and replica 4 (Angle 3) is 79.2510º.

Table 12: Basic values, mean and standard deviation of inter implant angulations in z-axis for Group B samples

Group B	Angle1(degrees)	Angle 2(degrees)	Angle 3(degrees)
B1	20.3105	32.1550	80.3939
B2	21.5634	31.2408	79.1013
B3	19.0224	31.3606	80.0151
B4	20.0708	30.1527	79.5556
B5	21.5951	32.2914	80.8058
B6	19.2540	31.2910	80.2021
B7	20.3712	32.0712	80.3657
B8	19.2050	30.0744	79.2657
B9	19.5831	31.1313	78.7647
B10	20.0156	31.1817	79.0849
Mean /S.D	20.0991/±0.90969	31.2950/±0.75840	79.7555/±0.69034

INFERENCE:

For Group B samples the mean inter implant angulation in z-axis between replica 1 and replica 2 (Angle 1) is 20.0991º, between replica 1 and replica 3 (Angle 2) is 31.2950º and between replica 1 and replica 4 (Angle 3) is 79.7555º.

Table 13: Comparison of mean inter implant distances for Control-Group R, Group A and Group B samples in x-axis

Group	D_1x(mm)	D_2x(mm)	D_3x(mm)
	Mean	**Mean**	**Mean**
R	8.0376	21.3496	29.1668
A	8.1078	21.4410	29.2497
B	8.0028	21.2902	29.1420
P value	0.402	0.037*	0.166

Note: * denotes significance at 5% level

INFERENCE:

On comparison of the mean inter implant distances in x-axis, D_1x and D_3x were statistically not significant while statistically significant differences were obtained in the D_2x values between Control-Group R, Group A and Group B means.

Table 14: Differences in mean inter implant distances between Control-Group R, Group A and Group B samples in x-axis

Group	ΔD_1x(mm)	ΔD_2x(mm)	ΔD_3x(mm)
A- R	0.0702	0.0914	0.0829
B-R	-0.0348	-0.0594	-0.0248
A-B	0.1050	0.1508	0.1077

Table 15: Comparison of mean inter implant distances for Control-Group R, Group A and Group B samples in y-axis

Group	D_1y(mm)	D_2y(mm)	D_3y(mm)
	Mean	**Mean**	**Mean**
R	4.8955	4.8923	2.9538
A	4.7619	4.7349	2.8444
B	5.0200	4.9722	3.1016
P value	0.093	0.103	0.014*

Note: * denotes significance at 5% level

INFERENCE: On comparison of the mean inter implant distances in y-axis, D_1y and D_2y were statistically not significant while statistically significant differences were obtained in the D_3x values between Control-Group R, Group A and Group B means.

Table 16: Differences in mean inter implant distances between Control-Group R, Group A and Group B samples in y-axis

Group	ΔD_1y(mm)	ΔD_2y(mm)	ΔD_3y(mm)
A-R	-0.1336	-0.1574	-0.1094
B-R	0.1245	0.0799	0.1478
A-B	-0.2581	-0.2373	-0.2572

Table 17: Comparison of mean of inter implant distances for Control - Group R, Group A and Group B samples in z-axis

Group	D_1z(mm)	D_2z(mm)	D_3z(mm)
	Mean	**Mean**	**Mean**
R	3.3556	2.9104	1.9786
A	3.5607	2.9575	1.7618
B	3.5766	2.8109	1.7915
P value	0.173	0.647	0.610

INFERENCE: On comparison of the mean inter implant distances in z-axis (D_1z, D_2z and D_3z) between the reference and the test groups, results were found to be statistically insignificant.

Table 18: Differences in mean inter implant distances for Control-Group R, Group A and Group B samples in z-axis

Group	ΔD_1z(mm)	ΔD_2z(mm)	ΔD_3z(mm)
A-R	0.2051	0.0471	-0.2168
B-R	0.2210	-0.0995	-0.1871
A-B	-0.0159	0.1466	-0.0297

Table 19: Comparison of mean inter implant angulations for Control- Group R, Group A and Group B samples in z-axis

Group	Angle 1 (degrees)	Angle 2 (degrees)	Angle 3(degrees)
	Mean	**Mean**	**Mean**
R	20.3853	32.1688	79.6519
A	19.5630	32.1061	79.2510
B	20.0991	31.2950	79.7555
P value	0.061	0.003*	0.127

Note: *denotes significance at 5% level

INFERENCE: On comparison of the mean inter implant angulations in z-axis, Angle 1 and Angle 3 were statistically not significant while statistically significant differences were obtained in the Angle 2 values between Control- Group R, Group A and Group B means.

Table 20: Differences in mean inter implant angulations for Control- Group R, Group A and Group B samples in z-axis

Group	Δ Angle 1(degrees)	Δ Angle 2(degrees)	Δ Angle 3 (degrees)
A-R	-0.8223	-0.0627	-0.4005
B-R	-0.2862	-0.8738	0.1036
A-B	-0.5361	0.8111	-0.5040

Table 21: Comparative evaluation of mean difference in inter implant distance between reference model (Control-Group R) and Group A and Group B in x-axis

Inter implant distance	Groups		Mean difference	P value
D_1x	Group A	Control-Group R	0.0702	0.740
	Group B	Control-Group R	-0.0348	0.928
	Group A	Group B	-0.1050	0.377
D_2x	Group A	Control-Group R	0.0914	0.375
	Group B	Control-Group R	-0.0594	0.654
	Group A	Group B	-0.1508	0.030*
D_3x	Group A	Control-Group R	0.0829	0.462
	Group B	Control-Group R	-0.0248	0.931
	Group A	Group B	0.1077	0.175

*****Denotes significance at 5% level

INFERENCE:

Significant difference was found in D_2x on comparison between Group A and Group B with p value of 0.030(P value < 0.05).

Table 22: Comparative evaluation of mean difference in inter implant distance between reference model (Control-Group R), Group A and Group B in y-axis

Inter implant distance	Groups		Mean difference	P value
D_1y	Group A	Control-Group R	-0.1336	0.601
	Group B	Control-Group R	0.1245	0.642
	Group A	Group B	-0.2581	0.077
D_2y	Group A	Control-Group R	-0.1574	0.464
	Group B	Control-Group R	0.0799	0.816
	Group A	Group B	-0.2373	0.090
D_3y	Group A	Control-Group R	-0.1094	0.514
	Group B	Control-Group R	0.1478	0.306
	Group A	Group B	-0.2572	0.011*

*****Denotes significance at 5% level

INFERENCE:

On comparing the mean differences between reference and test group, significant difference was found in D_3y between Group A and Group B with P value of 0.011 (P value < 0.05).

Table 23: Comparative evaluation of mean difference in inter implant distance between reference model (Control-Group R) and Group A and Group B in z-axis

Inter implant distance	Groups		Mean difference	P value
D_1z	Group A	Control-Group R	0.2051	0.224
	Group B	Control-Group R	0.2210	0.180
	Group A	Group B	-0.0159	0.986
D_2z	Group A	Control-Group R	0.0471	0.968
	Group B	Control-Group R	-0.0995	0.865
	Group A	Group B	0.1466	0.627
D_3z	Group A	Control-Group R	-0.2168	0.602
	Group B	Control-Group R	-0.1871	0.683
	Group A	Group B	-0.0297	0.985

INFERENCE:

On comparing the mean difference between reference model and test groups no significant differences were found.

Table 24: Comparative evaluation of mean difference in inter implant angulations between reference model (Control-Group R) and Group A and Group B in z-axis

Inter implant angulations	Groups		Mean difference	P value
Angle1	Group A	Control-Group R	-0.8223	0.074
	Group B	Control-Group R	-0.2862	0.703
	Group A	Group B	-0.5361	0.177
Angle 2	Group A	Control-Group R	-0.0627	0.947
	Group B	Control-Group R	-0.8738	0.015*
	Group A	Group B	0.8111	0.006*
Angle 3	Group A	Control-Group R	-0.4005	0.391
	Group B	Control-Group R	0.1036	0.937
	Group A	Group B	-0.5040	0.122

*****Denotes significance at 5% level

INFERENCE:

On comparing the mean differences between reference model and test groups, significant difference was found in Angle 2 between reference and Group B with P value of 0.015 and also between Group A and Group B with P value of 0.006(P value < 0.05).

DISCUSSION

Dental implant therapy has been widely used for the restoration of partially and fully edentulous patients. It is essential for long term successful implant prostheses to achieve a passive fit between the fixture and superstructure. A passive fit is defined as a very precise surface contact for the metal and it distributes functional load uniformly.[33] The passive fit between the implant and the framework of the prosthesis is critical for successful long term osseointegration.[6,23]

An understanding of the biomechanics of implant prosthodontics is critically important, since the use of a rigid framework will distribute forces directly to the transmucosal abutment connection, implant, and ultimately to the bone.[46] Ill-fitting implant frameworks may cause mechanical failures of the prosthesis and/ or implants, or biologic complications of the surrounding tissue.[34,49] Mechanical complications may include loosening of the prosthetic and abutment screws or fracture of areas components in the system. Biologic complications may include adverse tissue reactions, pain, tenderness, marginal bone loss, and loss of integration.[9,34]

Even though several strategies have been suggested to reduce distortion of the implant framework, the accuracy of the implant master cast plays a vital role in improving fit.[44,57] The accuracy of the implant cast depends on the type of implant impression technique, impression material, die material accuracy and the implant master cast technique.[38,57] Success in oral rehabilitation is dependent, in part, on the accurate registration of those structures that constitute the basis for prosthesis support. The impression which allows replication must be accurate and reproducible so that the resultant master cast precisely duplicates the clinical condition.

Implant level impression requires uses of implant copings. Copings can either be open tray impression copings or closed tray impression copings. The primary advantage of the open tray coping is that, the coping remains in the impression and the chances of error during reseating of the impression coping back into the impression is eliminated as the coping gets picked up in the impression. The concern of the angulated implants deforming the impression material upon removal of impression does not exist. But during fastening of the analog to the impression coping there are chances of rotation of coping inside the impression thereby causing a rotational distortion.[2,14,29,57]

In case of closed tray tapered copings, the copings are not picked up in the impression rather after impression is made the copings are attached to the analogs and reseated into the impression thus the complete seating of the analog to the coping is ensured thereby eliminating errors that occur in the vertical axis. But due to reseating on the coping-analog assembly into the impression errors can occur in inter implant distance in the horizontal axis.[2,14,57]

Considering the ease of impression making like closed tray technique and direct accurate transfer of impression copings like a open tray technique the press fit coping has the advantages of both open tray and closed tray copings.[43,48] Since studies comparing the accuracy of the press fit coping with the other impression techniques are lacking this study was aimed to analyse the accuracy between closed tray press fit copings and open tray splinted impression copings.

An edentulous mandibular model with four implant replica in the anterior region was used as the reference model (Control-Group R) in this study. This was to resemble a clinical situation where in a minimum of four implants are required to give a fixed implant prosthesis.

Custom trays (open and closed tray) with an even spacer thickness of 3mm was fabricated on a spaced primary cast to ensure standardization.[53] This ensured that bulk of the impression material was the same in all the impressions made. The custom trays were made of light cure resin sheets that had a even thickness of 2mm to ensure rigidity and to standardize the tray thickness. The trays had three stops incorporated in them for proper orientation of the trays in the reference model during impression making.

Among the materials used for impression making, polyether has been advocated for edentulous multiple implant retained restorations.[15,26,42,46,50] Therefore, medium body polyether was used as the impression material for all the test groups. It was machine mixed (Pentamix 2) in order to avoid errors resulting from improper mix and was delivered around the impression copings using a Pentasyringe to avoid defects around the impression copings.

For direct impression technique, the custom trays and the resin splint were coated with a uniform layer of adhesive to prevent distortion of the impression and to reduce the movement of the splinted impression coping in the impression when the screws were removed. During impression making, it was made sure that all the three stops were positioned properly in the reference model to ensure equal bulk of impression material in all the impressions. When the implant replicas were tightened to the impression copings in the impression, the torque wrench was not used to avoid rotation of copings in the impression.

All casts were poured with the same amount of die stone as per manufacturer's instructions. All the casts were measured for a specific dimension using a Coordinate Measuring Machine(CMM) with an accuracy of ±5µm.[31] Inter implant distances in x, y and z axes and inter implant angulations in z axis were calculated for the reference model and master casts. All measurements were made in reference to implant replica number 1. The measurements for the master casts were compared with that of the reference model to calculate the relative distortion. Since the implant prosthesis connects the abutments together, the amount of strain in the implant prosthetic-implant bone system is related to the relative position of the implant abutments to one another and not to any external reference point.

Therefore, for clinical relevance, relative distortion has been suggested than absolute distortion analysis.

The results were divided into four categories namely, distortions in the x, y, z axes and the inter implant rotational distortion. A total of nine distances and three angles were compared separately in order to understand as to where distortion occur the most.

The differences in inter implant distance in x-axis ranged from 0.0702mm (70.2 µm) to 0.0914mm(91.4 µm) for impressions with press fit copings(A-R) and 0.0248mm(24.8 µm) to -0.0594mm (-59.4 µm) for open tray copings(B-R). The differences in D_1x, D_2x and D_3x values were similar for both the test groups and when compared to the reference model were statistically insignificant. The x-axis values (D_1x, D_2x and D_3x) have increased for Group A (press fit) master casts and decreased for Group B (open tray) master casts. The casts obtained from open tray impression were closer to the reference model in x-axis than those obtained from press fit impressions.

Spector reported an error of up to 20 - 180 µm in x-axis for the resin splinted group in comparison with indirect impression techniques.[50] Humphries reported a difference of 108µm for resin splinted impressions and Hsu found an error of up to 65µm. Thus in comparison to the reference model the differences in x- axis obtained in this study was within the similar range when compared with previous studies. Though there is a statistical difference seen in D_2x, significant difference was found only between Group A and Group B which is not relevant as there is no statistical difference between the reference model and test groups.

The differences in inter implant distance in y-axis ranged from -0.1094mm (-109.4 µm) to -0.1574mm (-157.4µm) for impressions with press fit copings (A-R) and -0.7990mm (-79.9 µm) to 0.1478mm (147.8 µm) for open tray copings (B-R). The differences in D_1y, D_2y and D_3y values were similar for both the test groups when compared to the reference model and were not statistically significant. The y-axis values have decreased for Group A master casts and increased for Group B (open tray) master casts. Casts obtained from open tray splinted impression techniques were closer to the reference model in y-axis than those obtained from press fit impression technique.

Spector in his study has reported a distortion of 80µm in y- axis[50] and Philips has reported an error of about 53µm in his study comparing the accuracy between three impression techniques.[46] Though there is a statistical difference seen in D_3y, significant difference was found only between Group A and Group B which is not relevant as there is no statistical difference between the reference model and test groups.

In the present study, casts obtained from open tray splinted impression techniques have exhibited decrease in x-axis values and increase in y-axis values when compared with reference model. The shrinkage of pattern resin could be explained as the possible reason for the open tray impression copings moving closer to each other resulting in lesser inter implant distances in x-axis and greater inter implant distance in y-axis.

Shrinkage of polyether towards the tray could be the reason for increase of distance in x-axis and decrease in y-axis for master casts obtained with press fit impression copings.

The difference in inter implant distance in z-axis ranged from -0.2168mm (-216.8 µm) to 0.2240mm (224 µm) for impressions with press fit copings and -0.1871mm (-187.1 µm) to 0.2210mm (221 µm) for open tray copings. The differences in D_1z, D_2z, D_3z for both the test groups when compared for the reference model were not statistically significant when compared with the reference model values. The differences seen for both the groups are similar to each other. Also they are higher than the values obtained in previous studies.[21,46] This can be attributed to the non-standardized finger pressure during connection of the implant replica to the press fit coping after making the impression.

Carr in his study has reported variability of up to 20µm due to repeated screw fastening while Jemt stated that a vertical gap of 50-100µm is acceptable as it can be compensated by an extra half turn of the screw connecting the different implant components.[30] Though the values are not coinciding with previous studies[30] there is no statistical significant difference among all the values in z-axis.

The difference in inter implant angulation in z-axis ranged from -0.0627 degrees to -0.8223 degrees for impressions with press fit copings and 0.1036 degrees to -0.2862 degrees for open tray copings. The differences in Angle1 and Angle 3 for all the test groups were not statistically significant when compared with the reference model values while statistically significant variation was seen in Angle 2 values between reference model and Group B. Angular differences seen more in open tray technique can be because of screwing of replicas to the impression coping in the impression. Considering the method of connecting the replica to the coping in press fit technique, there is no rotation of coping inside the impression. This has resulted in lesser angular differences. Therefore, they exhibit lesser rotational misfit.

Reports of 1.6 to 5.3 degree tolerance between implant and abutment[15] and the existence of rotational freedom of about 5.5 degrees between implant and abutment suggests that the values obtained in this study were within clinically acceptable limits.[11] The minimum rotational discrepancies obtained in this study also reinforce the need for rigid impression material like polyether to prevent rotational distortions. But there exists no research as to how much of torque polyether can withstand before the copings rotates.[57]

The present study has shown that both the impression techniques exhibit inaccuracies in all three axes and did not replicate the exact position of replicas in the reference model. But all the values were within clinically acceptable levels. On comparison between the reference group and test groups there was no statistical significance.

Considering the ease of impression making with press fit impression copings, level of accuracy similar to open tray splinted impression technique and also the possibility of adjusting the plastic press fit copings, this technique can be advocated as a reliable implant level technique for multiple implants.

The limitations of this study include that the present study was limited till the measurement of distances and angulations between the replicas. But framework was not fabricated which would help to find out whether the discrepancies occurred would interfere with the fit of framework. Further studies can be conducted clinically and the amount of discrepancy that occur can be studied. Studies can also be done by increasing the sample numbers. The influence of implant angulation and its effect in accuracy of impressions with press fit impression copings can be studied.

CONCLUSION

The following conclusions were drawn within the limitations of this in vitro study, which comparatively evaluated the accuracy of implant level impressions obtained with closed tray press fit impression copings and open tray splinted impression copings for multiple implants:

1. The mean inter implant distances in x axis for casts obtained from impressions using closed tray press fit impression copings (Group A) were 8.1078mm, 21.4410mm and 29.2497mm for D_1x, D_2x and D_3x respectively.
2. The mean inter implant distances in y axis for casts obtained from impressions using closed tray press fit impression copings (Group A) were 4.7619mm, 4.7349mm and 2.8444mm for D_1y, D_2y and D_3y respectively.
3. The mean inter implant distances in z axis for casts obtained from impressions using closed tray press fit impression copings (Group A) were 3.5607mm, 2.9575mm and 1.7618mm for D_1z, D_2z and D_3z respectively.
4. The mean inter implant angulations in z axis for casts obtained from impressions using closed tray press fit impression copings (Group A) were 19.5630º, 32.1061° and 79.2510º for Angle1, Angle 2 and Angle 3 respectively.

5. The mean inter implant distances in x axis for casts obtained from impressions using open tray splinted impression copings (Group B) were 8.0028mm, 21.2902mm and 29.1420mm for D_1x, D_2x and D_3x respectively.
6. The mean inter implant distances in y axis for casts obtained from impressions using open tray splinted impression copings (Group B) were 5.0200mm, 4.9722mm and 3.1016mm for D_1y, D_2y and D_3y respectively.
7. The mean inter implant distances in z axis for casts obtained from impressions using open tray splinted impression copings (Group B) were 3.5766mm, 2.8109mm and 1.7915mm for D_1z, D_2z and D_3z respectively.
8. The mean inter implant angulations in z axis for casts obtained from impressions using open tray splinted impression copings (Group B) were 20.0991º, 31.2950º and 79.7555º for Angle1, Angle 2 and Angle 3 respectively.
9. On comparison with the reference model (Control-Group R), casts obtained from impressions using closed tray press fit impression copings (Group A) exhibited differences in the inter implant distances in the range from 0.0702mm to 0.0914 mm (70.2µm to 91.4 µm) in x-axis, while casts obtained from impressions using open tray splinted impression copings (Group B) exhibited differences in the range from -0.0594mm to -0.0248mm (-59.4 µm to -24.8 µm) in x-axis. On

comparing the mean values between the reference model and the test groups no significant difference was found between reference model and Group A or Group B but statistically significant difference was found in x-axis in D_2x (replica 1 and 3) between Group A and Group B (P value <0.05)

10. On comparison with the reference model (Control-Group R), casts obtained from impressions using closed tray press fit impression copings (Group A) exhibited differences in the inter implant distances in the range from -0.1090mm to -0.1570mm (-109 µm to -157 µm) in y- axis while casts obtained from impressions using open tray splinted impression copings (Group B) exhibited differences in the range from 0.0799mm to 0.1478mm (79.9 µm to 147.8µm) in y-axis. On comparing the mean values between the reference model and the test groups no significant difference was found between reference model and Group A or Group B but statistically significant difference was found in y-axis in D_3y (replica 1 and 4) between Group A and Group B(P value < 0.05).
11. On comparison with the reference model (Control-Group R), casts obtained from impressions using press fit impression copings (Group A) exhibited differences in the inter implant distances in the range from -0.2168 mm to 0.2051 mm (-216.8µm to 205.1µm) in z-axis while casts obtained from impressions using open tray splinted impression copings (Group B) exhibited differences in the range from

-0.1871 mm to 0.2210 mm (-187.1µm to 221µm) in z-axis. On comparing the mean values between the reference model and the test groups no statistically significant difference was found between the groups.

12. On comparison with the reference model (Control-Group R), casts obtained from impressions using closed tray press fit impression copings (Group A) exhibited differences in the inter implant angulations in the range from -0.0627º to -0.8223º in z-axis while casts obtained from impressions using open tray impression copings (Group B) exhibited differences in the range from -0.8738º to 0.1036º in z-axis. On comparing the mean values between the reference model and the test groups no significant difference was found between reference model and Group A but statistically significant difference was found in z-axis in Angle 2 (replica 1 and 3) between reference model and Group B and also between Group A and Group B (P value < 0.05).

SUMMARY

This study comparatively evaluated the accuracy of implant level impressions obtained with closed tray press fit impression copings and open tray splinted impression copings for multiple implants.

A reference model of the edentulous mandible with four implant replicas in the anterior region was fabricated in heat cure acrylic resin and was used as control in this study (Control-Group R). The impression techniques were divided into two groups as closed tray technique with press fit impression copings and open tray technique with splinted impression copings and grouped as Group A and Group B respectively. Ten impressions of the reference models were made in each group with custom trays using polyether impression material. The impressions were poured using type IV dental stone and the retrieved master casts were evaluated for three dimensional accuracy of inter implant relationship using a Coordinate measuring machine. Nine inter implant distances, three each in x, y and z axes and three inter implant angles in z axis were measured from the reference model and the master casts. The differences in the inter implant distances in x, y and z axes and the inter implant angular differences in the z-axis, in relation to the reference model were measured for all the casts. The results were tabulated and statistically analysed using one way ANOVA and Student-Newman-Keuls test.

The impressions made with closed tray press fit impression copings (Group A) showed differences in inter implant distances in x, y and z axis and minimum angular differences in z axis in comparison with the reference model (Control-Group R). The difference in distances and angulations does not have statistical significance.

The impressions made with open tray splinted impression copings (Group B) showed differences in inter implant distances in x, y and z axis in comparison with the reference model (Control-Group R). The differences in distances do not have statistical significance. The angulations in z axis exhibited difference at one of the angles between replica 1 and 3 (Angle 2) which has statistical significance.

The results obtained in this study indicates that none of the impression techniques showed exact reproduction of the reference model, and the test casts exhibited differences in inter implant distances and angulations. The difference in inter implant distances in x, y, and z axis and angulation in z-axis does not have statistical significance in all the measurements except for Angle 2 (between reference model and Group B). On comparative evaluation of master casts obtained from implant level impressions with closed tray press fit impression copings and open tray splinted impression copings, the accuracy of these casts is comparable to the reference model.

In the literature, both open and closed tray impression techniques have been advocated and majority of the authors have recommended the open tray technique. Open tray technique has the advantage of picking up the impression coping in the impression, decreased deformation of impression material and accurate recording of the position of angled implants, while it has the disadvantage of rotation of impression coping within the impression during connection of implant replica. Press fit impression coping is easier to manipulate, time saving and more comfortable for both the clinician and patient. These copings can be picked up in the impression similar to open tray impression copings and also do not rotate in the impression due to the absence of screwing of implant replica. The plastic press fit copings can also be adjusted in situations of angled implants.

Considering the ease of impression making with press fit copings and its level of accuracy similar to splinted open tray impression technique, press fit impression technique can be advocated as a reliable impression technique for obtaining accurate implant level impression for multiple implants. The selection of impression technique can be based on the clinical situation and the individual clinician’s preference.

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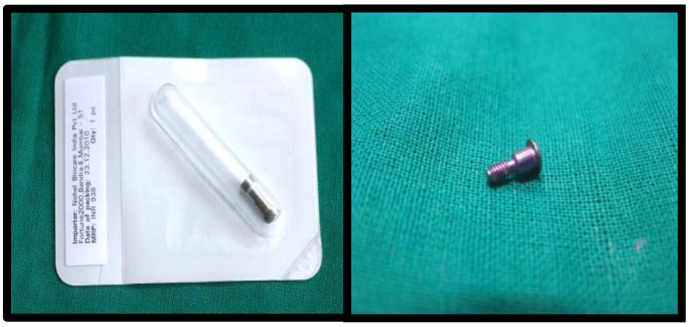
MATERIALS

Fig.1: Modelling wax

Fig.2: Closed tray impression coping



a **b**

Fig.3a: Implant replica, 3b: Cover screw

Fig.4: Press fit impression copings

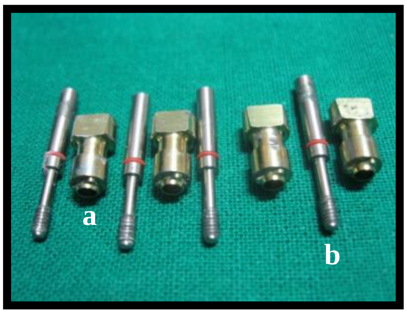


Fig.5a: Open tray impression copings
5b: Guide pins

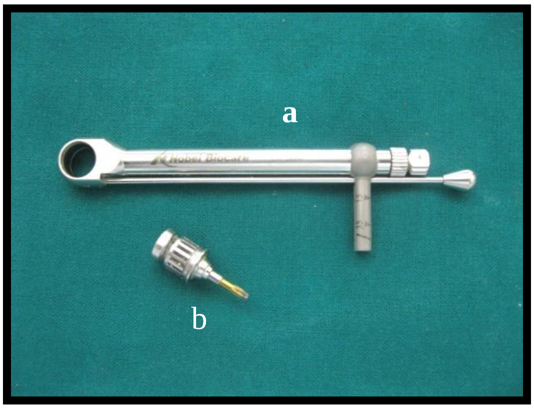


Fig.6a: Manual prosthetic torque wrench

6b: Screw driver

Fig.7: Heat cure acrylic resin

7a: Polymer; 7b: Monomer; 7c: Cold mould seal

Fig.8: Irreversible hydrocolloid

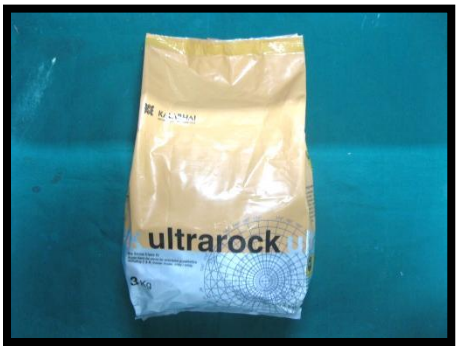


Fig.9: Type IV dental stone

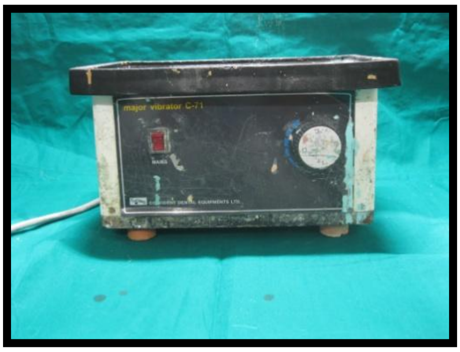


Fig 10: Vibrator

Fig.11: Light cure unit

Fig.12: Polyether adhesive

Fig.13: Light cure resin sheet

Fig.14: Polyether impression material

Fig.15: Autopolymerizing pattern resin

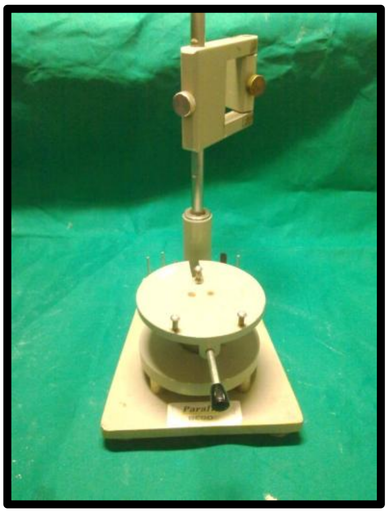


Fig.16: Dental surveyor

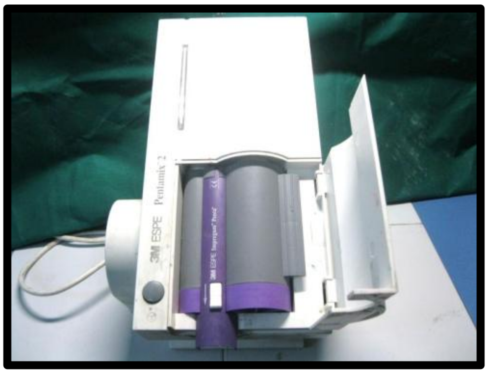


Fig.17: Pentamix automixing unit

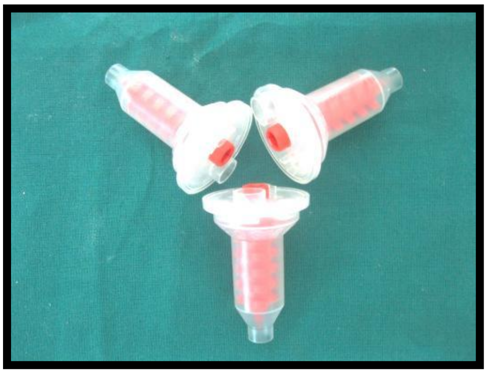


Fig.18: Pentamix mixing tips

CUSTOM TRAYS FABRICATION

a

b

Fig.22a: Reference model with tapered impression copings

22b: Irreversible hydrocolloid impression with repositioned tapered impression copings

Fig.23: Primary cast

Fig.24: Wax spacer adapted to the primary cast

Fig.25: Irreversible hydrocolloid impression

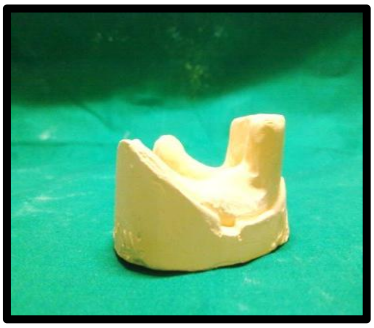


Fig.26: Spaced primary cast

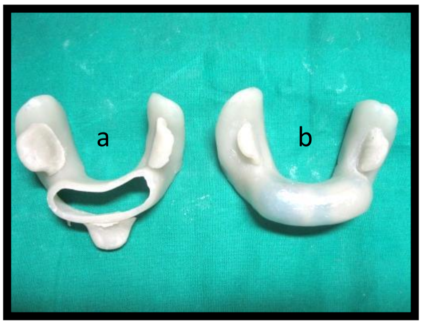


Fig. 27a : Finished custom trays in light cure resin(open tray)
27b : Finished custom trays in light cure resin(closed tray)

CLOSED TRAY IMPRESSION TECHNIQUE (GROUP A)

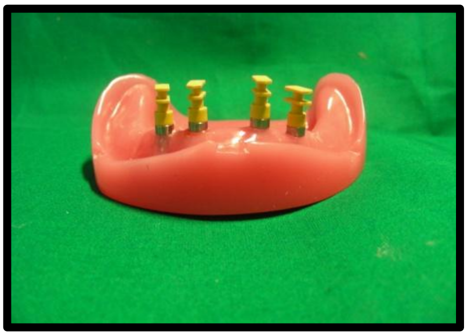


Fig.28:Pressfit copings attached to reference model

Fig.29: Adhesive applied to closed tray

Fig.30: Tray loaded with polyether

Fig.31: Impression made with Polyether impression material

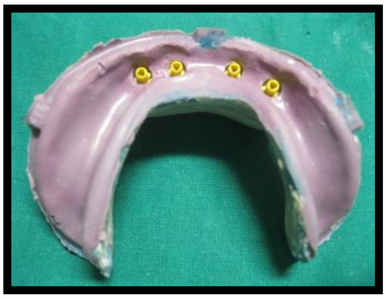


Fig.32: Closed tray impression

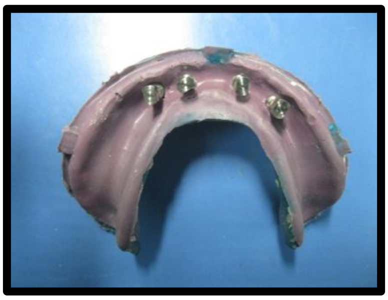


Fig.33: Implant replicas connected to press fit impression copings

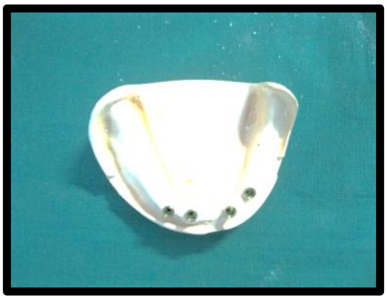


Fig. 34: Master Cast (Group A)

OPEN TRAY IMPRESSION TECHNIQUE (GROUP B)

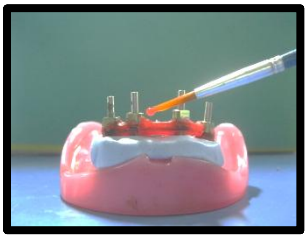


Fig.35a: Brush bead application of pattern resin over the index

Fig.35b : Splinted open tray copings attached to reference model

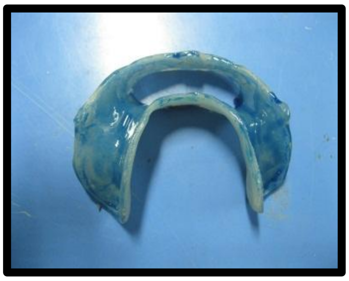


Fig.36: Adhesive applied to open tray

Fig.37: Impression made with polyether impression material

Fig.38: Open tray impression

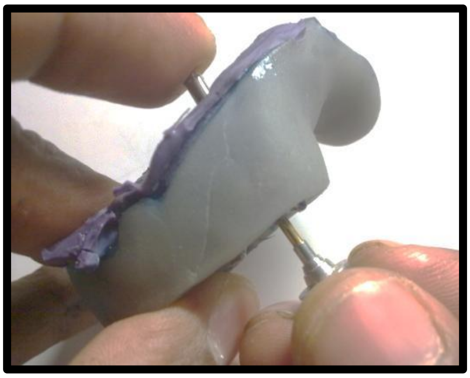


Fig.39: Connecting implant replicas to open tray impression copings

Fig.40: Master cast (Group B)

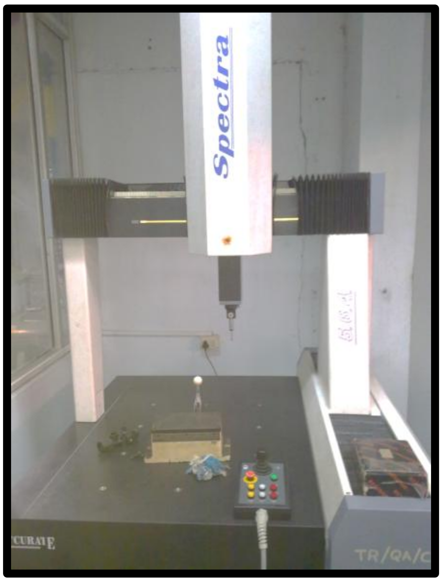


Fig.41 : Coordinate Measuring Machine(CMM)

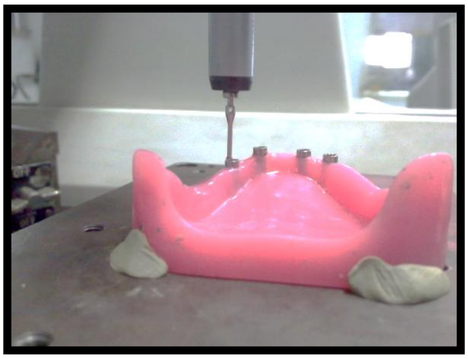


Fig.42: Measuring reference model using CMM

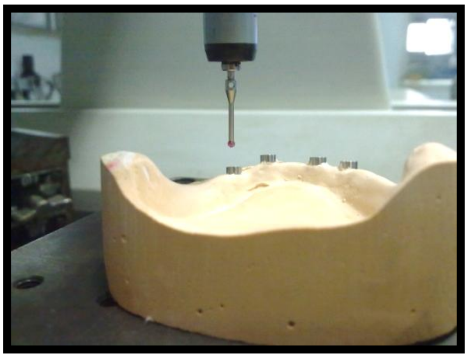
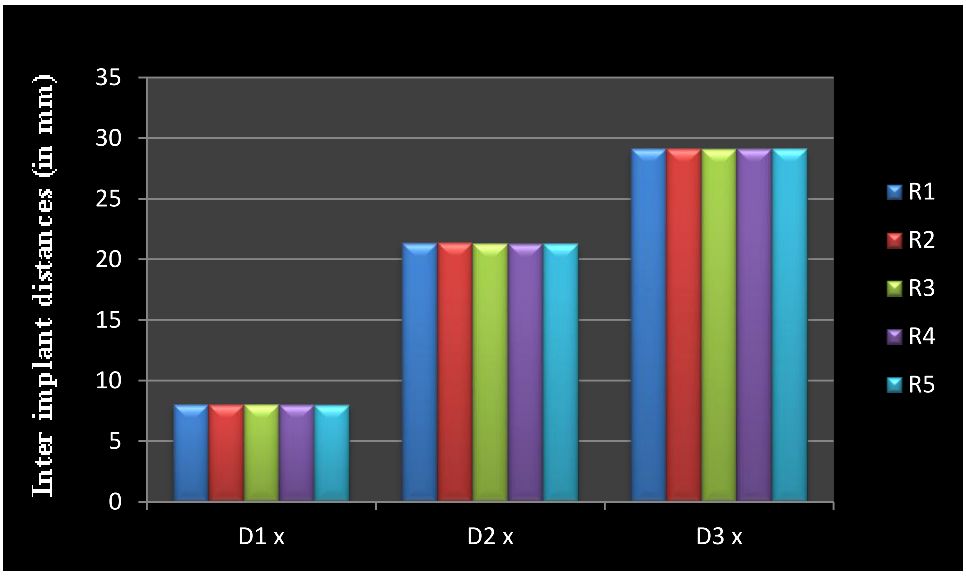
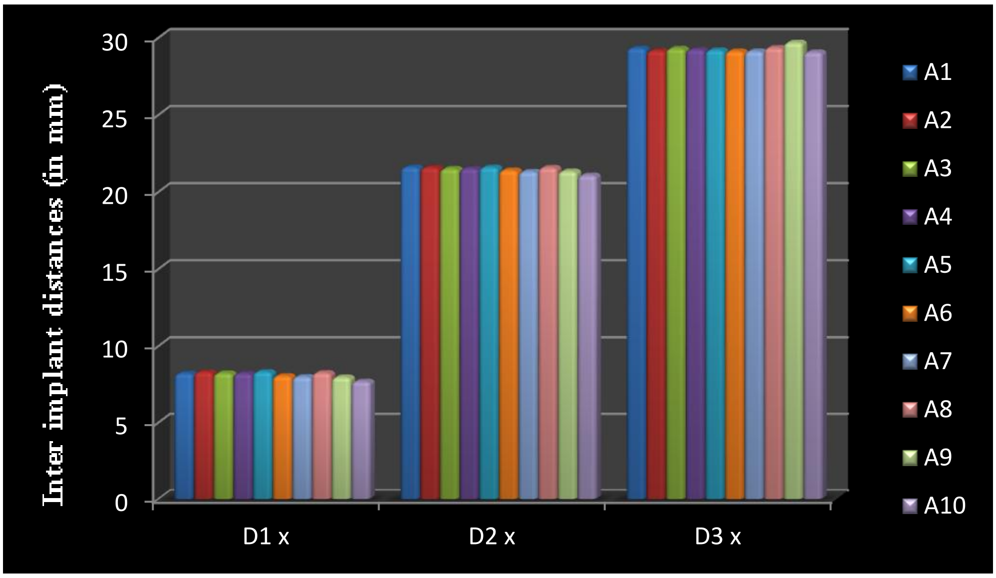


Fig.43: Measuring master cast using CMM

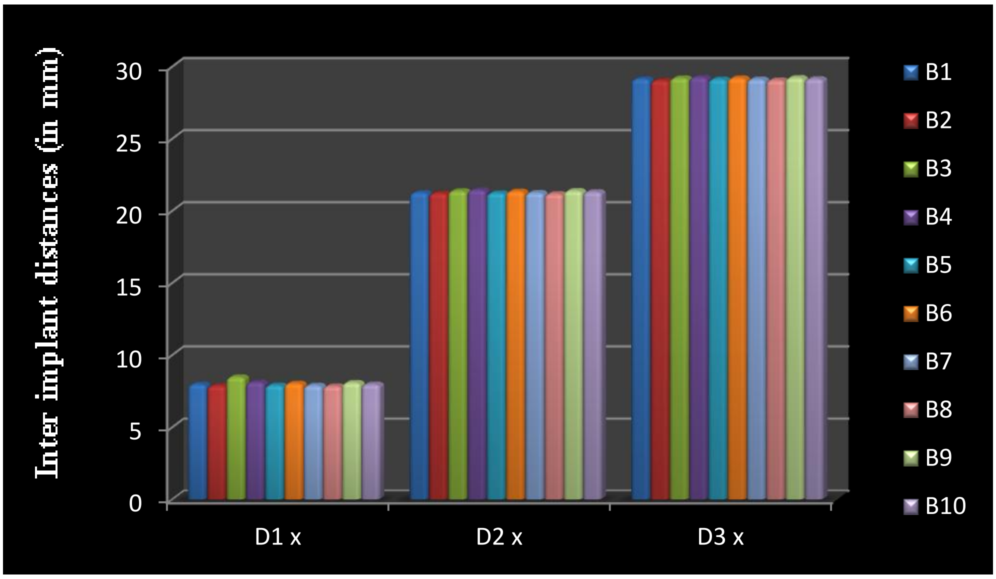
Graph 1: Basic values of inter implant distances in x-axis for the reference model (Control-Group R)



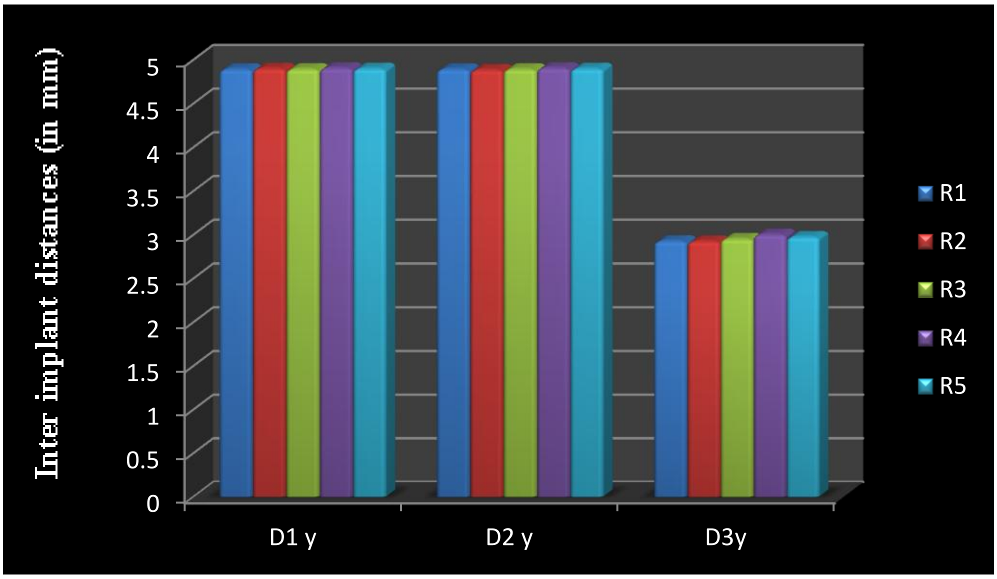
Graph 2: Basic values of inter implant distances in x-axis for Group A samples



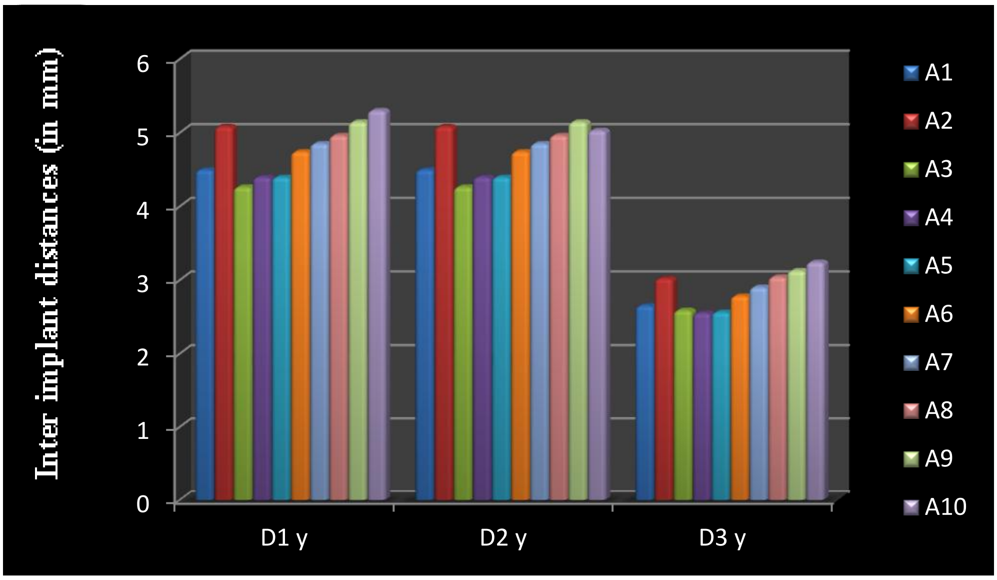
Graph 3: Basic values of inter implant distances in x-axis for Group B samples



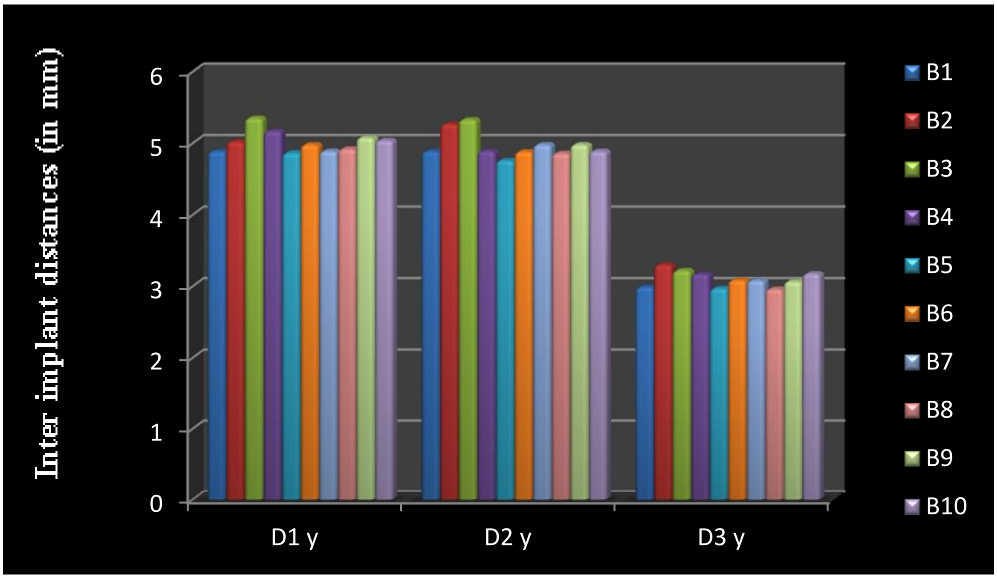
Graph 4: Basic values of inter implant distances in y-axis for the reference model (Control-Group R)



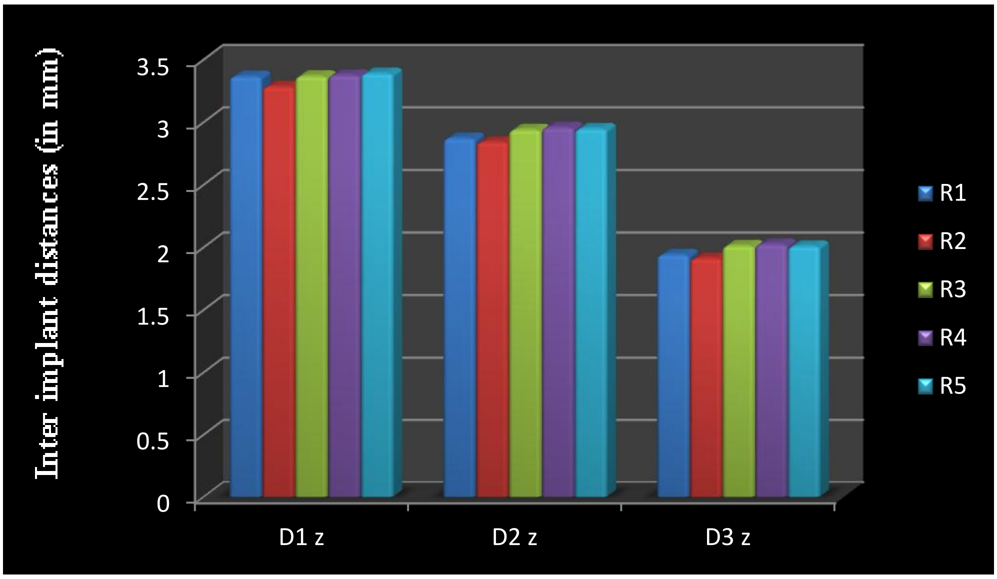
Graph 5: Basic values of inter implant distances in y-axis for Group A samples



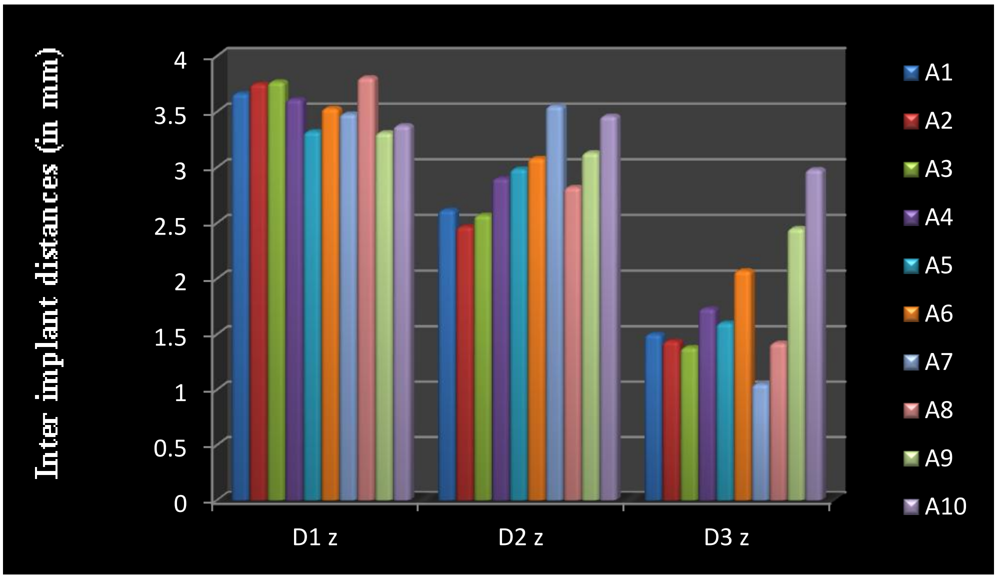
Graph 6: Basic values of inter implant distances in y-axis for Group B samples



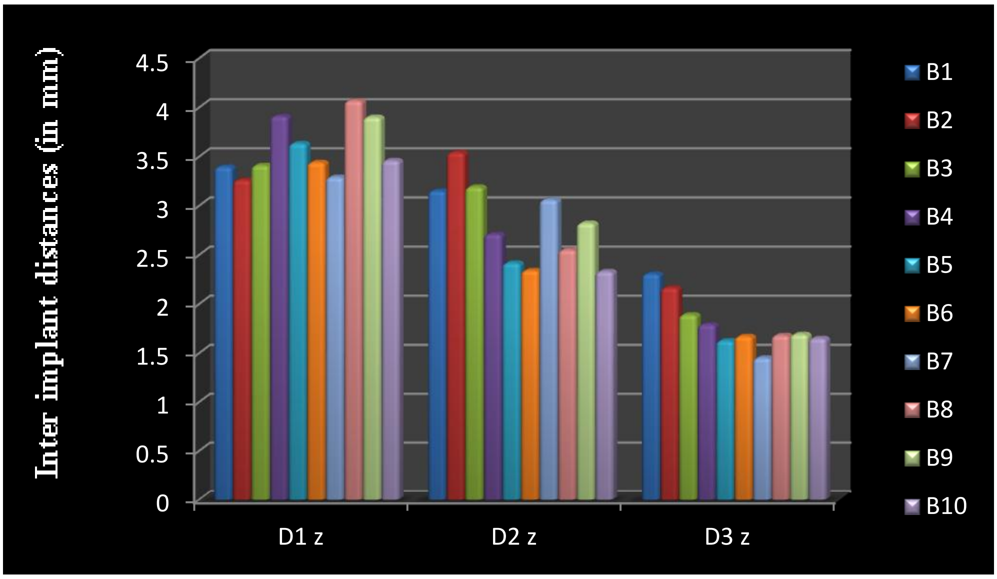
Graph 7: Basic values of inter implant distance in z- axis for reference model (Control-Group R)



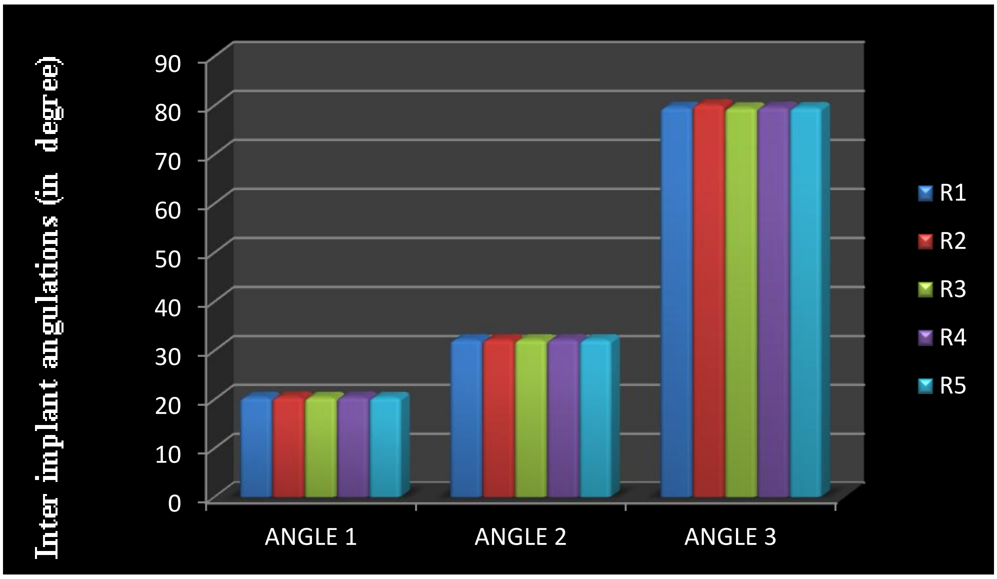
Graph 8: Basic values of inter implant distances in z-axis for Group A samples



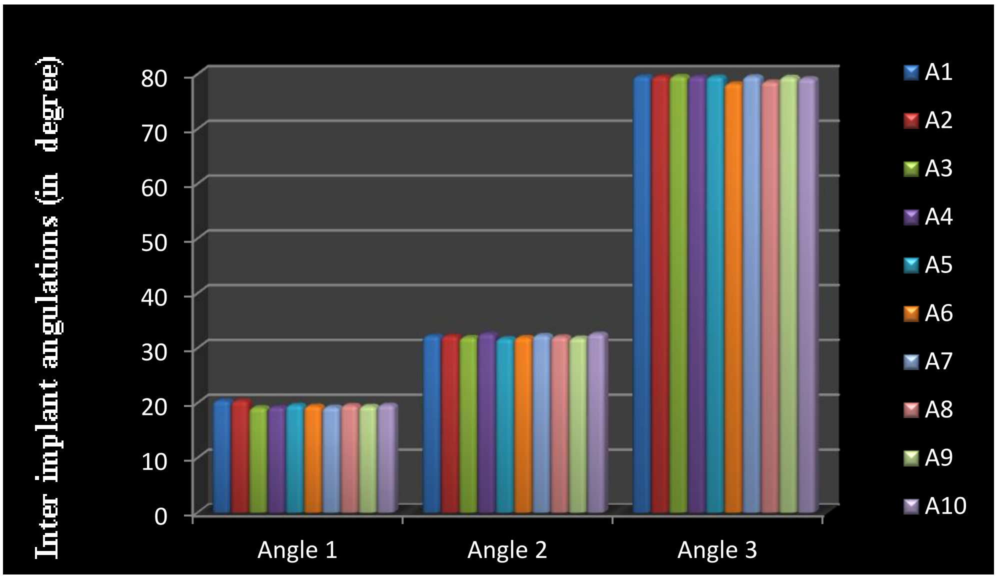
Graph 9: Basic values of inter implant distances in z-axis for Group B samples



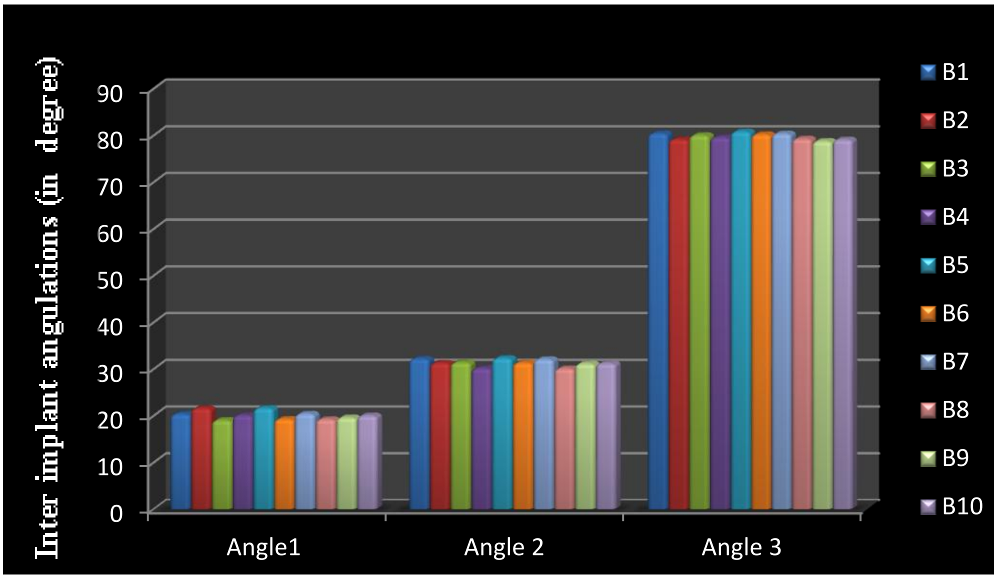
Graph 10: Basic values of inter implant angulations in z-axis for reference model (Control-Group R)



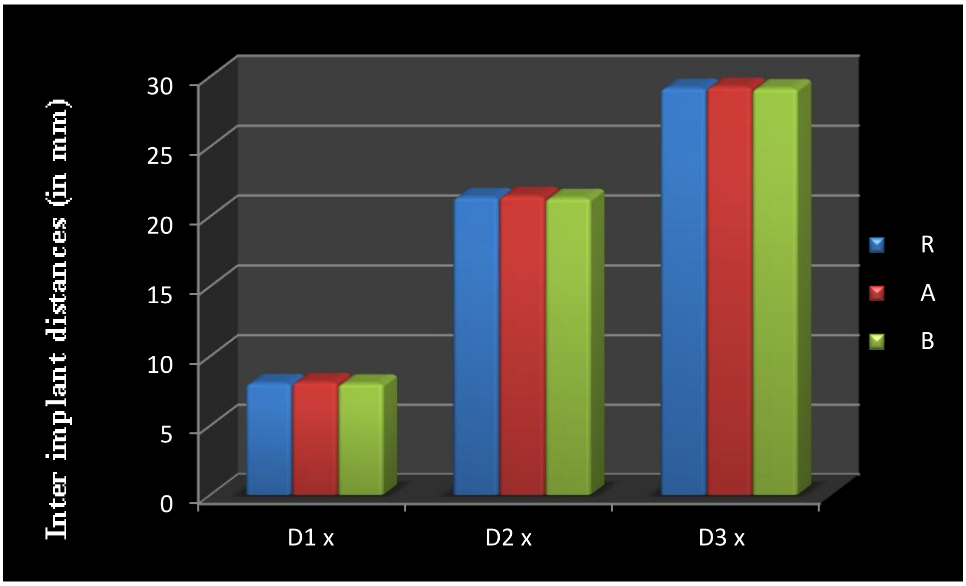
Graph 11: Basic values of inter implant angulations in z-axis for Group A samples



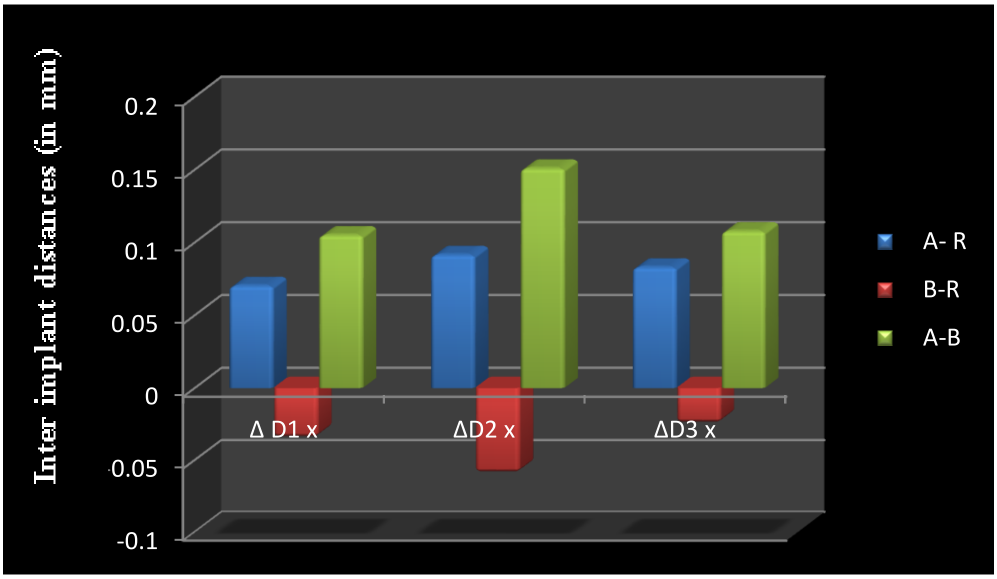
Graph 12: Basic values of inter implant angulations in z-axis for Group B samples



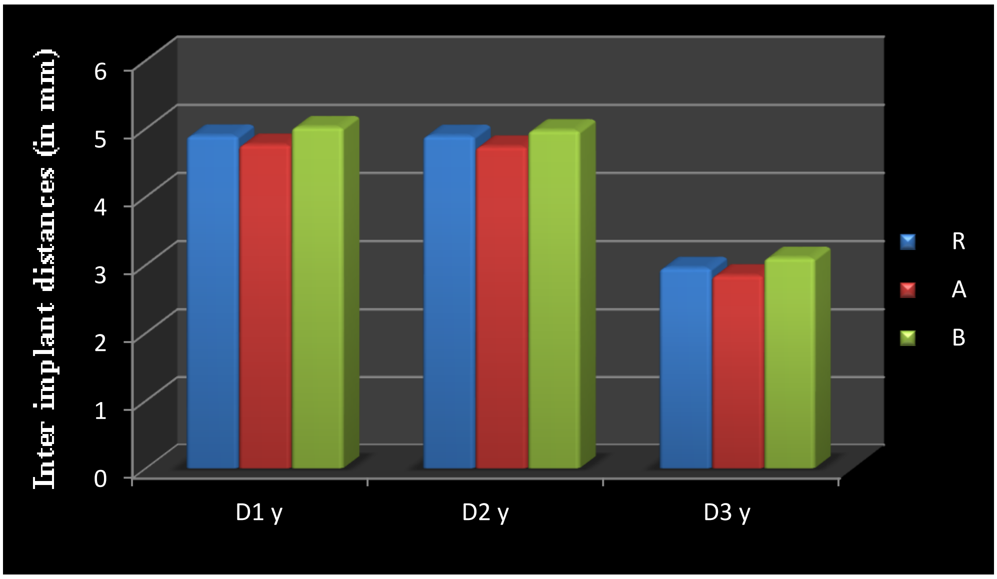
Graph 13: Comparison of mean inter implant distances for Control-Group R, Group A and Group B samples in x-axis



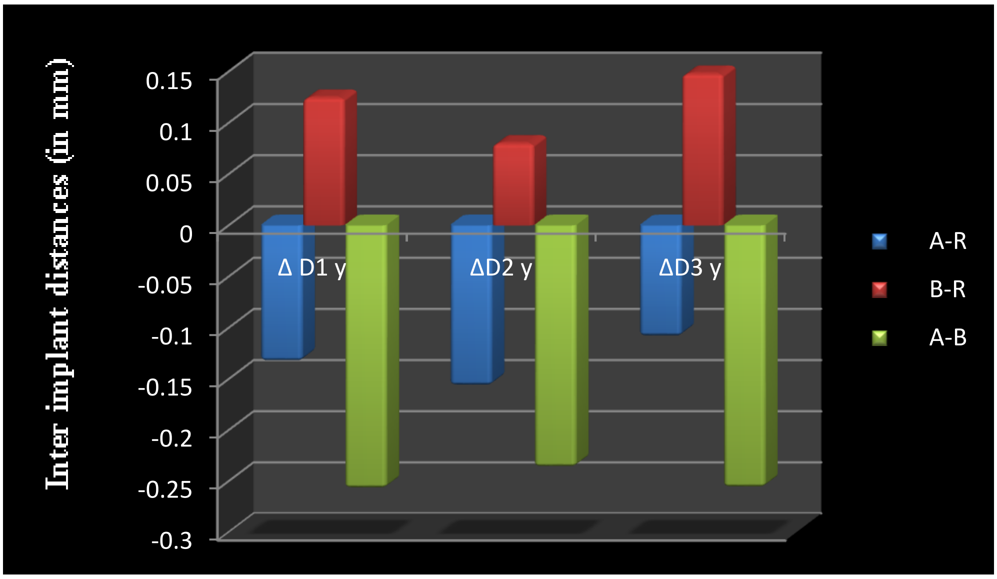
Graph 14: Differences in mean inter implant distances between Control-Group R, Group A and Group B samples in x-axis



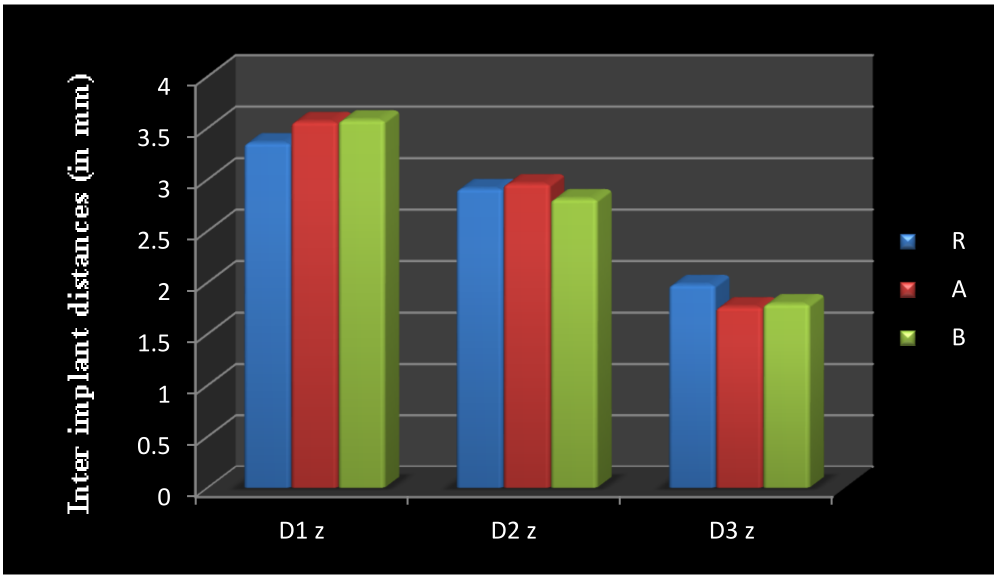
Graph 15: Comparison of mean inter implant distances for Control-Group R, Group A and Group B samples in y-axis



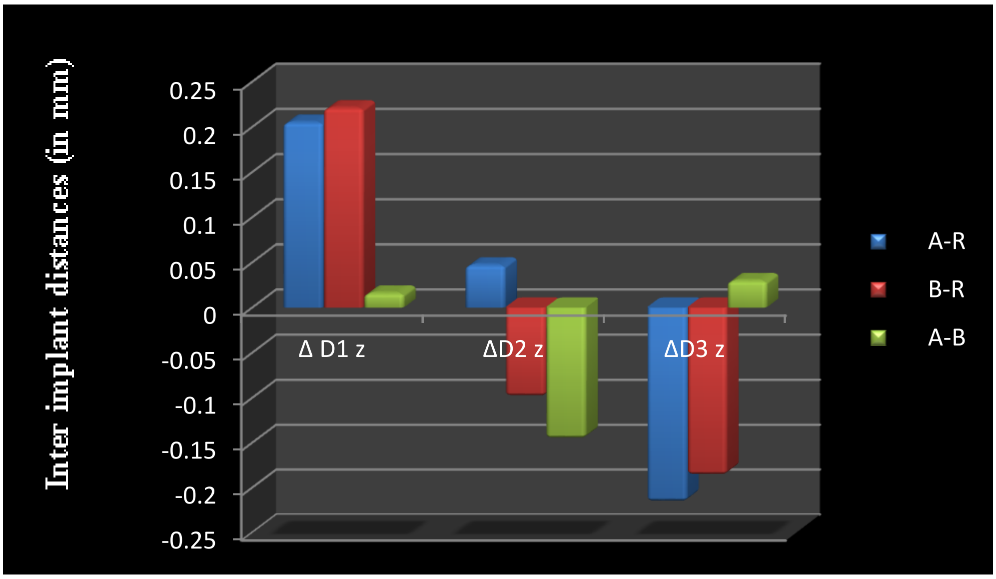
Graph 16: Differences in mean inter implant distances between Control-Group R, Group A and Group B samples in y-axis



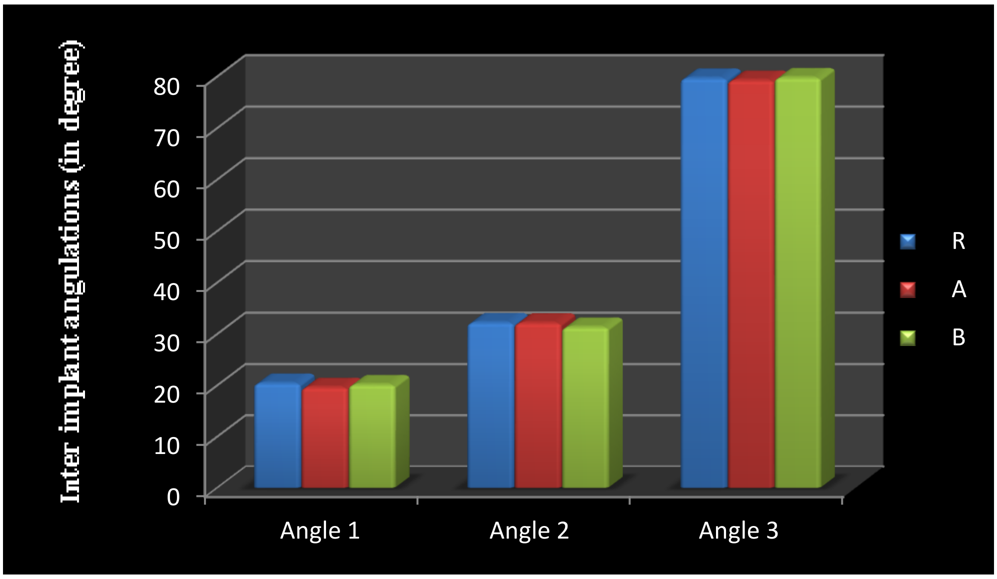
Graph 17: Comparison of mean inter implant distances for Control-Group R, Group A and Group B samples in z-axis



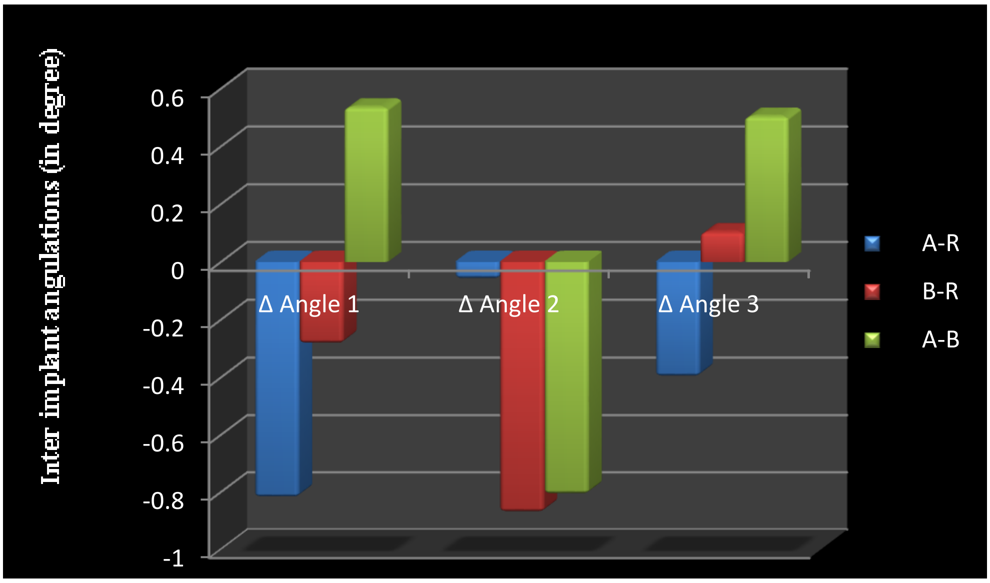
Graph 18: Differences in mean inter implant distances between Control-Group R, Group A and Group B samples in z-axis



Graph 19: Comparison of mean inter implant angulations for Control-Group R, Group A and Group B samples in z-axis



Graph 20: Differences in mean inter implant angulations between Control-Group R, Group A and Group B samples in z-axis



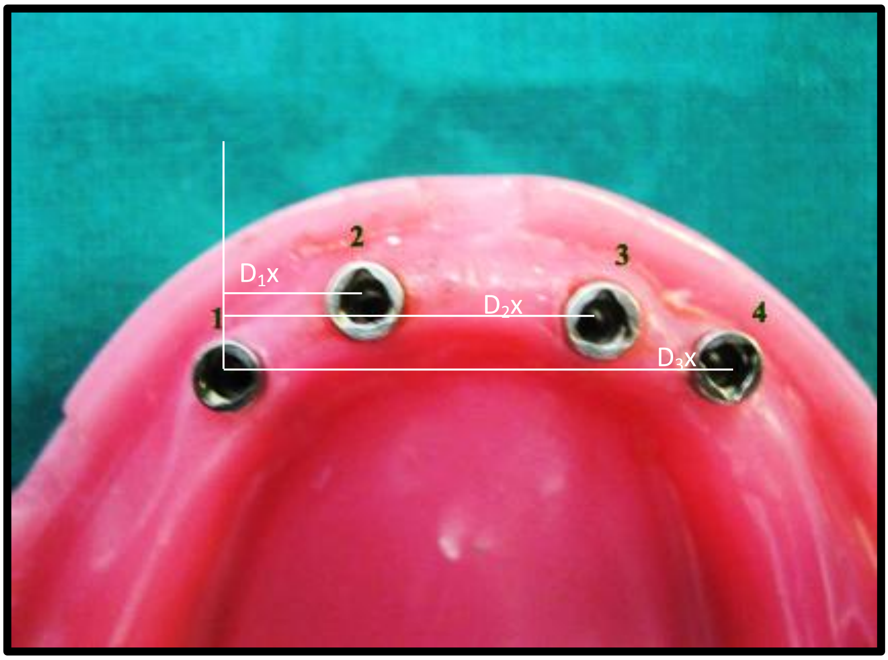


Fig.44: Inter implant distances in x-axis
D_1x- distance between replica 1 and 2
D_2x -distance between replica 1 and 3
D_3x -distance between replica 1 and 4

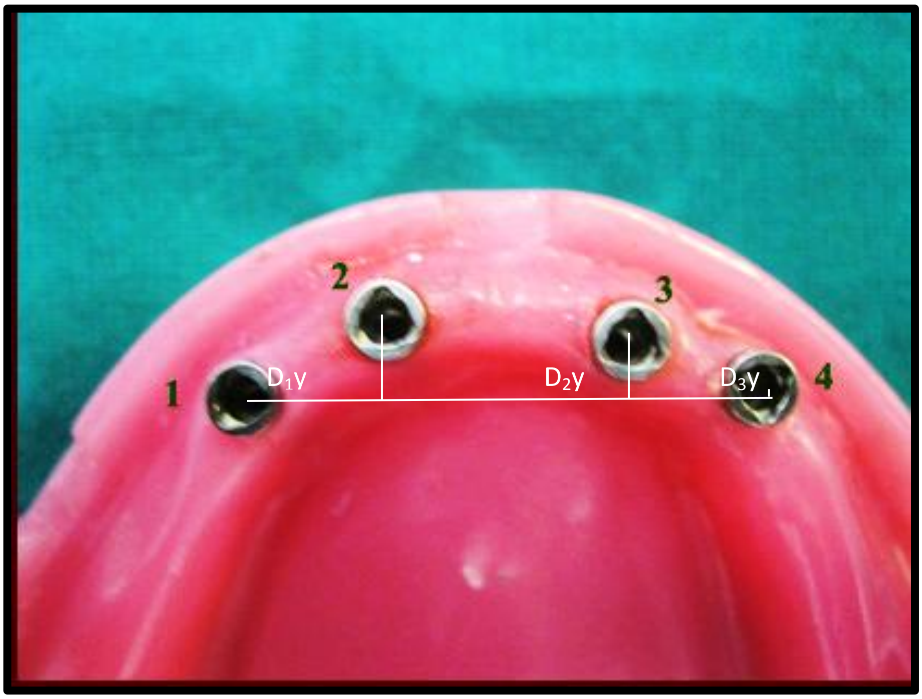


Fig.45: Inter implant distances in y-axis
D_1y- distance between replica 1 and 2
D_2y -distance between replica 1 and 3
D_3y -distance between replica 1 and 4

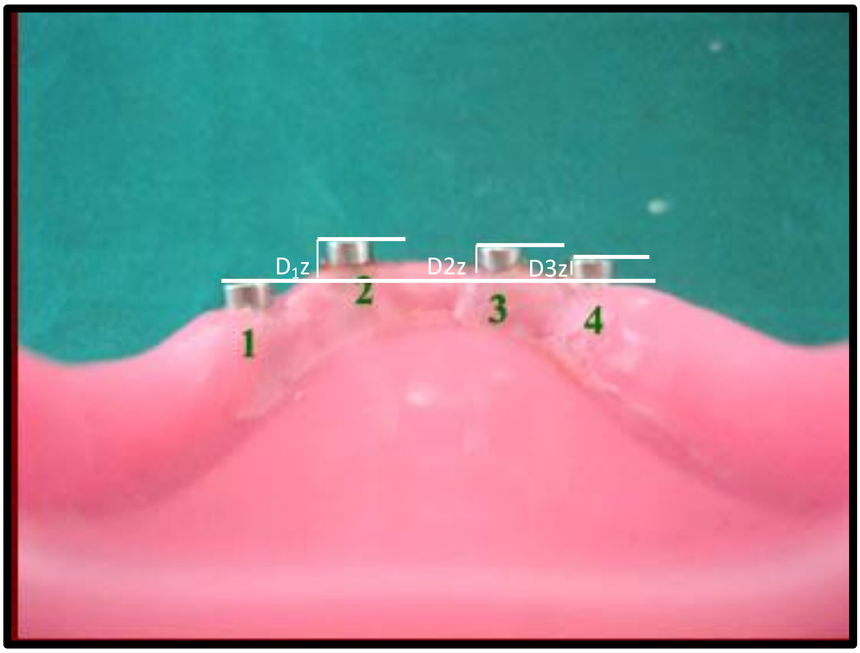


Fig.46: Inter implant distances in z-axis

D_1z- distance between replica 1 and 2

D_2z -distance between replica 1 and 3

D_3z -distance between replica 1 and 4

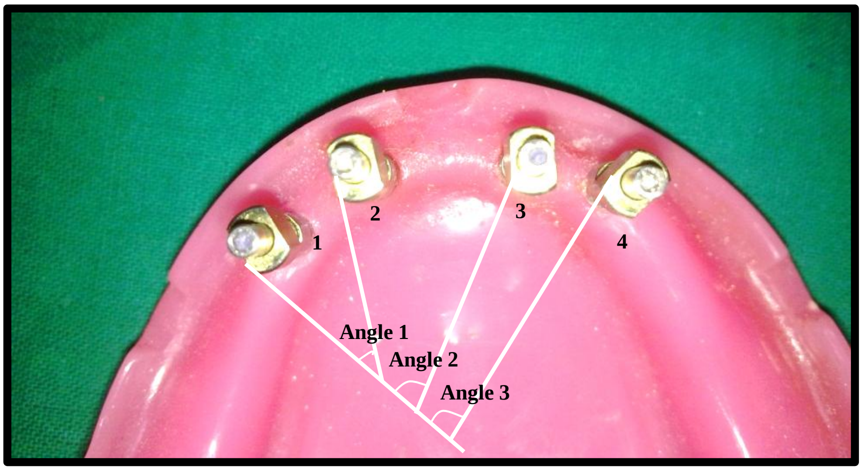


Fig.47: Inter implant angulations in z-axis

Angle1 - angle between replica 1 and 2

Angle 2 - angle between replica 1 and 3

Angle 3 - angle between replica 1 and 4